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DESIGN · PRODUCTION · MATERIALS

Vol. 43 No. 572 **NOVEMBER, 1953** PRICE: 3s. 6d.

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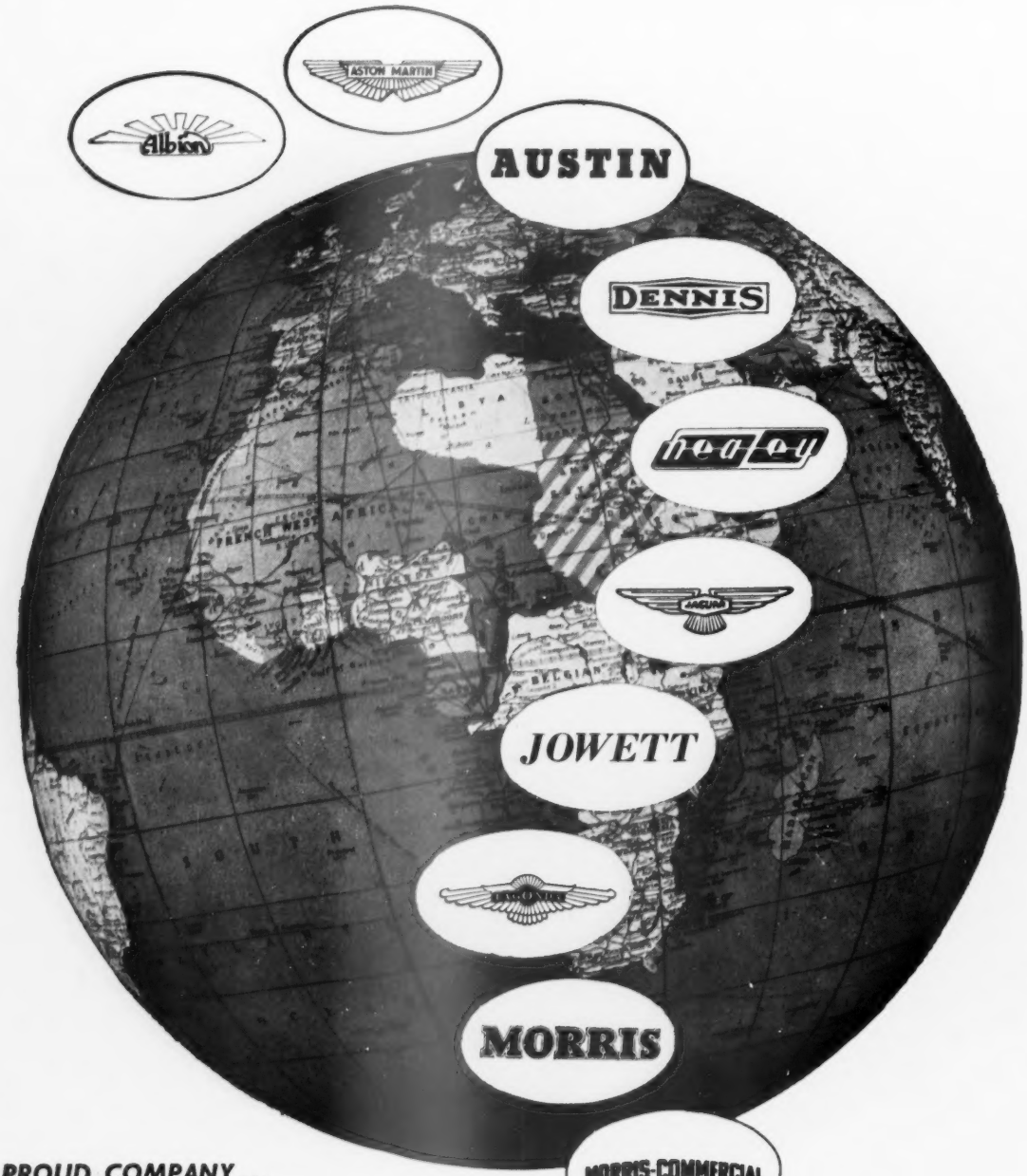

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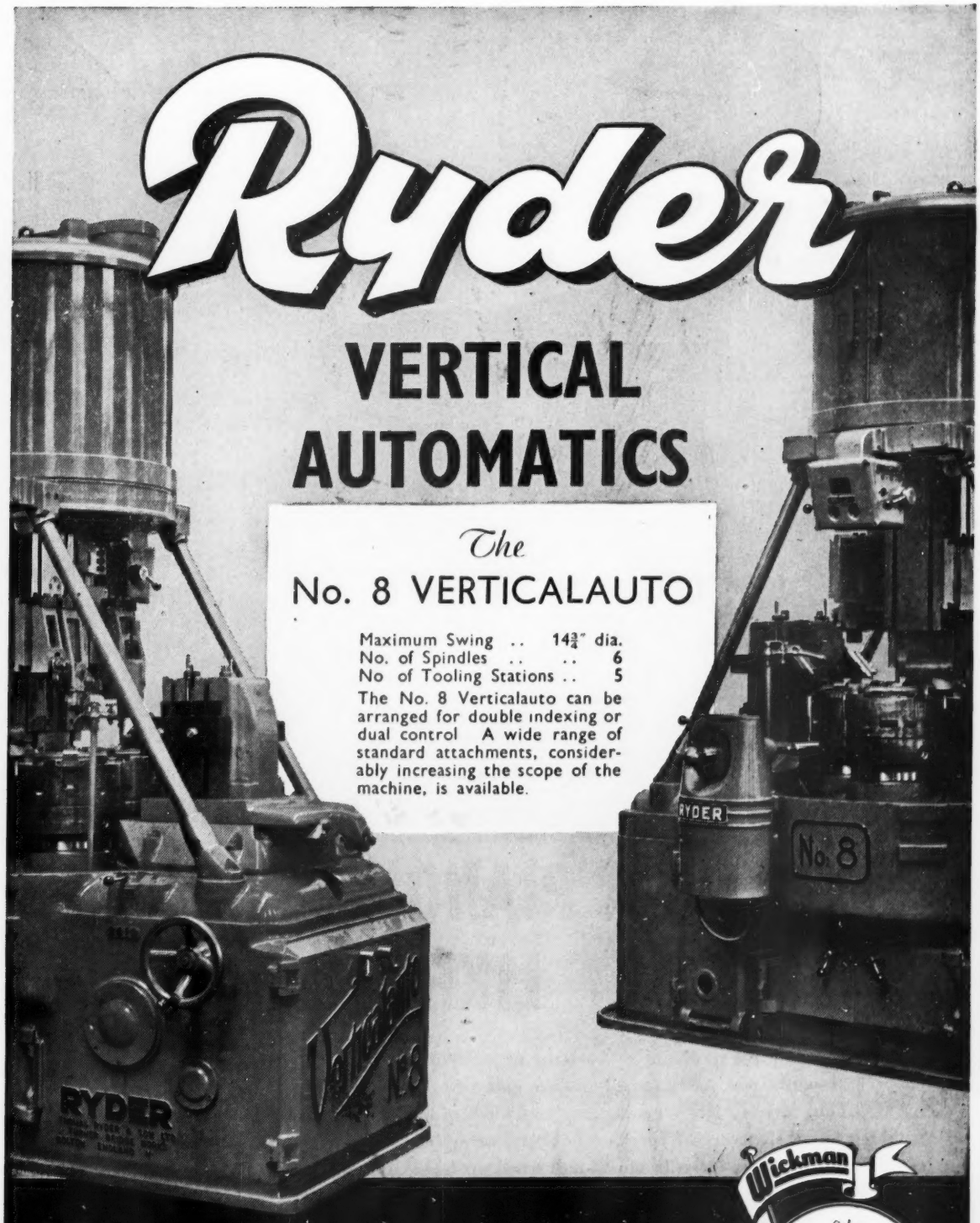

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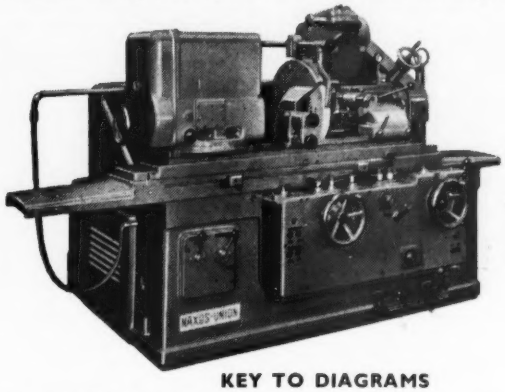
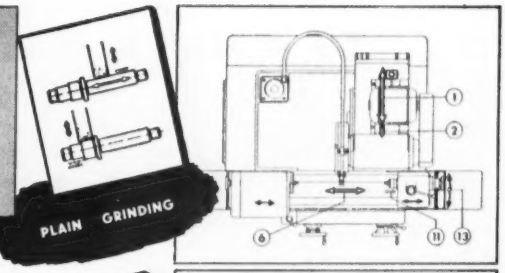
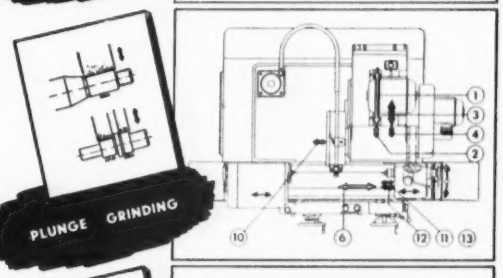
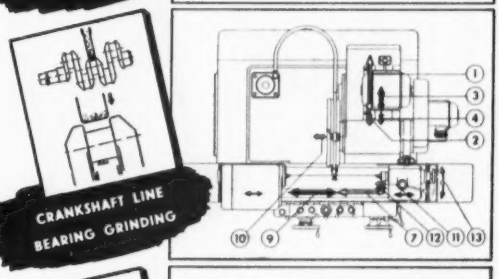
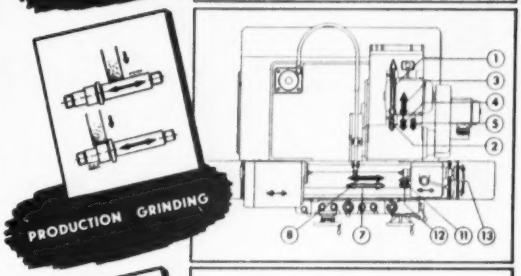


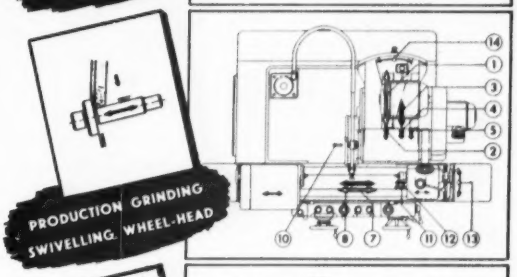
Type RU300 Universal Grinding Machine

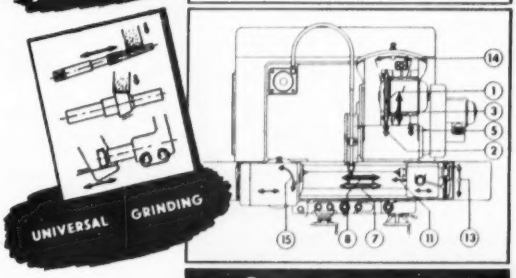












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THIN ARROWS Possibility of adjustment.

1. Hand movement.
2. Fine adjustment by hand.
3. Hydraulic quick adjustment.
4. Hydraulic plunge-cut motion.
5. Automatic fine adjustment.
6. Hand movement, one speed.
7. Hand movement, two speeds.
8. Hydraulic movement with reversal.
9. Hydraulic fast motion.
10. Axial movement.
11. Return motion by hand.
12. Hydraulic return motion.
13. Can be swivelled.
14. Can be swivelled.
15. Can be swivelled.

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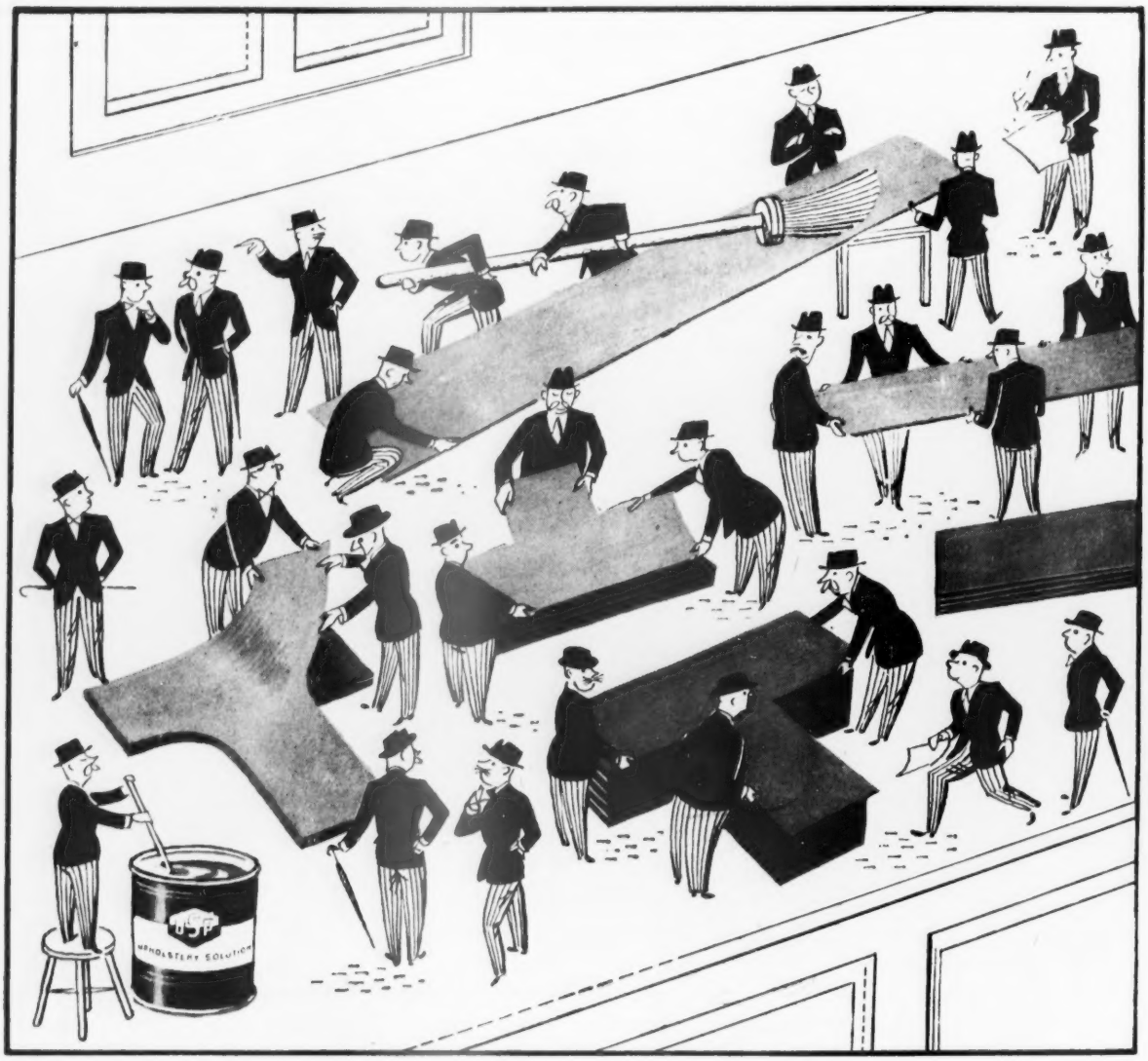

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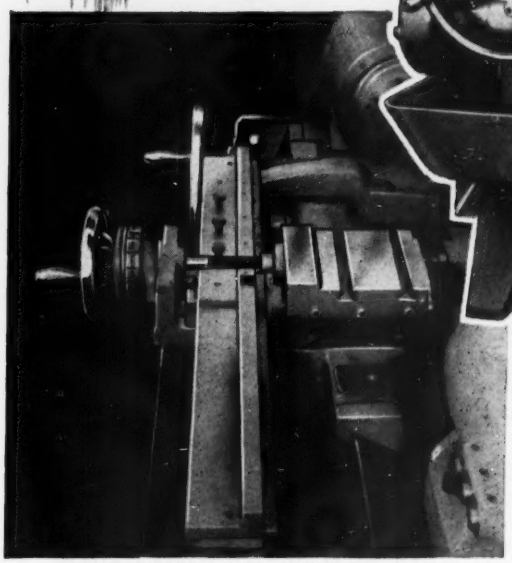

FRONT TAPER AND FORM TURNING ATTACHMENT showing the former rail without former. This is for use with a single tool where a form is to be repeated accurately. The lead screw and hand wheel control work diameter.

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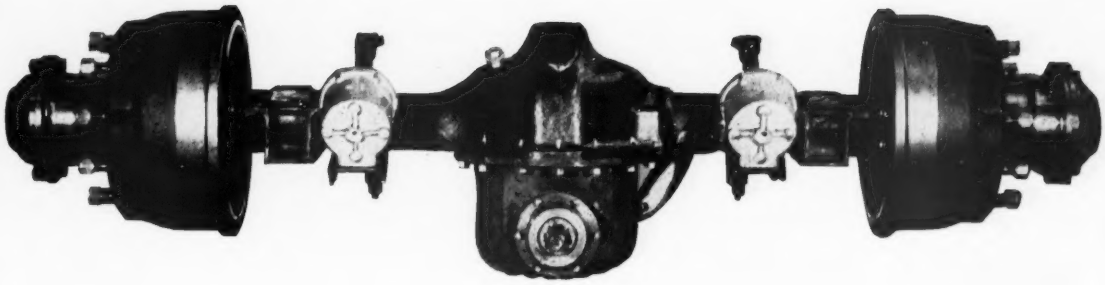

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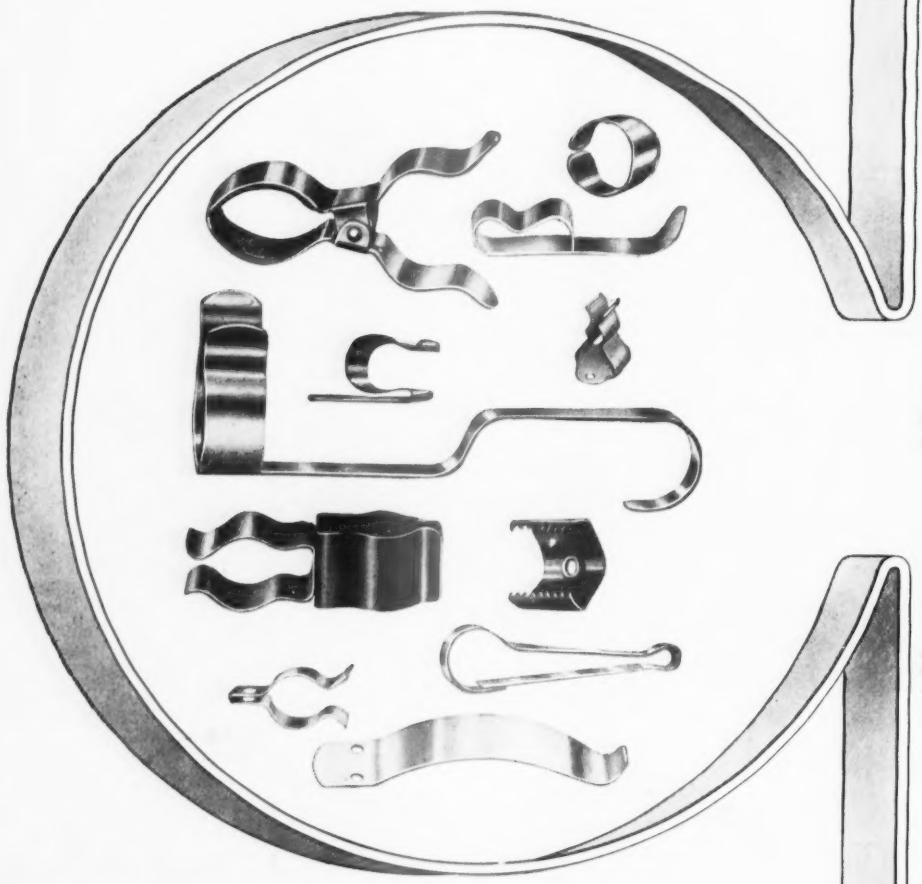

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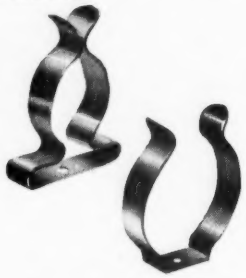

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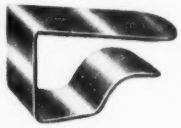

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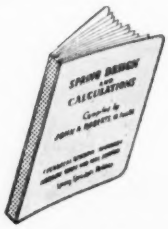

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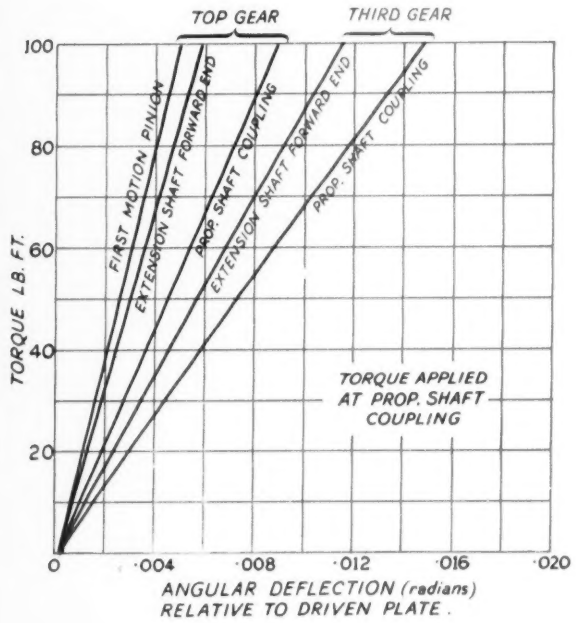
TRANSMISSION CONSIDERATIONS 5

RATTLE (2)

In the preceding article of this series, we saw that torsional vibrations of a shaft can produce the transmission fault known as rattle — a fluctuation or alternation of the drive at frequencies very much higher than those associated with judder.

Little difficulty is found in envisaging these vibrations in such a component as a propeller shaft. Somewhat different is the case of the comparatively short pieces in a gearbox. The equivalent spring rates of these parts have been measured, however, and it is known that they cover a fairly wide range.

In the four-speed box of a well-known medium-weight car, for instance, the effective stiffness of the mainshaft is approximately 14 times greater than that of the layshaft due to deflections which include the twist of the shaft itself and the tooth deflections in the indirect gears. In this particular unit, the stem shaft and the



extension shaft have values between those cited but are a good deal nearer to the layshaft's than to the mainshaft's.

These facts serve to emphasise the elasticity of components which might possibly escape suspicion in a preliminary investigation of rattle. Admittedly the layshaft is not loaded while the direct drive is in operation. Even so, however, this gearbox shows a static angular deflection of just over half a degree between the input and output ends when a torque of 100 lb. ft. is applied.

When the third gear is engaged, of course, the picture is quite different. Then, in effect, the layshaft is substituted for the mainshaft and the overall static deflection jumps to well over a degree if a torque of 100 lb. ft. is applied to the input shaft and is resisted at the output end of the box.

Instructive figures have been obtained from a series of experiments with a gearbox coupled in turn to a variety of clutch plates, each of the latter having a centre more or less different from the others. These tests were devised to study two principal factors, the resonance of the clutch-and-gearbox assembly and the ratio between the amplitude of the oscillations at the two ends of the assembly.

With four clutch plates differing only in the characteristics of their damper springs, the ratio of output amplitude to input amplitude varied from 6.3 to 1 in one case to 12.6 to 1 in another, all other things being equal. In short, one clutch damper was twice as effective as the other in controlling torsional vibration within the gearbox.

As to resonance, it is noteworthy that this varied only from 4200 to 4700 oscillations per minute, despite the difference of clutch damping. The inference would seem to be that the resonance of this assembly depends very much more upon the gearbox than upon the clutch.

This brings us to another point. Observation and analysis of very many cases suggests strongly that the originating disturbance or initiator of most torsional vibration in the transmission system is to be found in the engine. In other words, the frequency of vibration or oscillation usually ties in with the frequency of the impulses generated by the engine.

The gearbox just mentioned normally operates with a four-cylinder engine. Consequently it receives two impulses per revolution. At engine speeds of 2100 r.p.m. to 2350 r.p.m., therefore, it would receive 4200 to 4700 impulses per minute. From the experimental results one would expect gearbox rattle to occur somewhere within that speed range according to which particular clutch centre was used.

By reason of this connection the investigator has a valuable guide to the location of transmission rattle. Although the stethoscope technique may be helpful, noises have a most deceitful habit of travelling along metal. It may often be useful, therefore, to note the approximate engine speed at which the rattle occurs and to convert this into impulses per minute, according to the number of cylinders.

From this figure one knows with reasonable certainty the natural frequency (or possibly its harmonic) of the component which is in trouble. Experience may suggest a short list of parts which could possibly have that frequency. Failing this, there can be experimental or mathematical determination of the natural frequency of any component which may be under suspicion.

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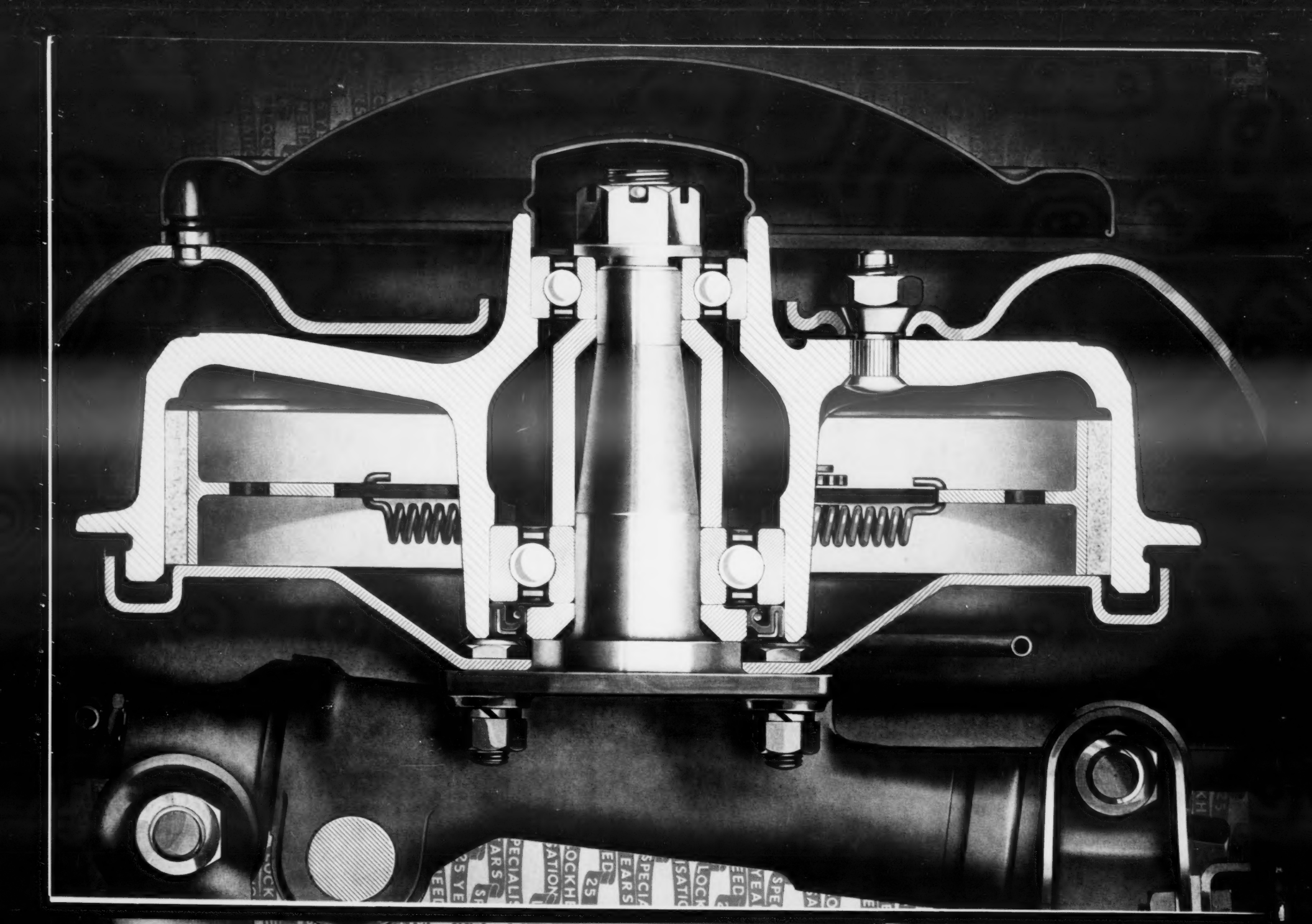

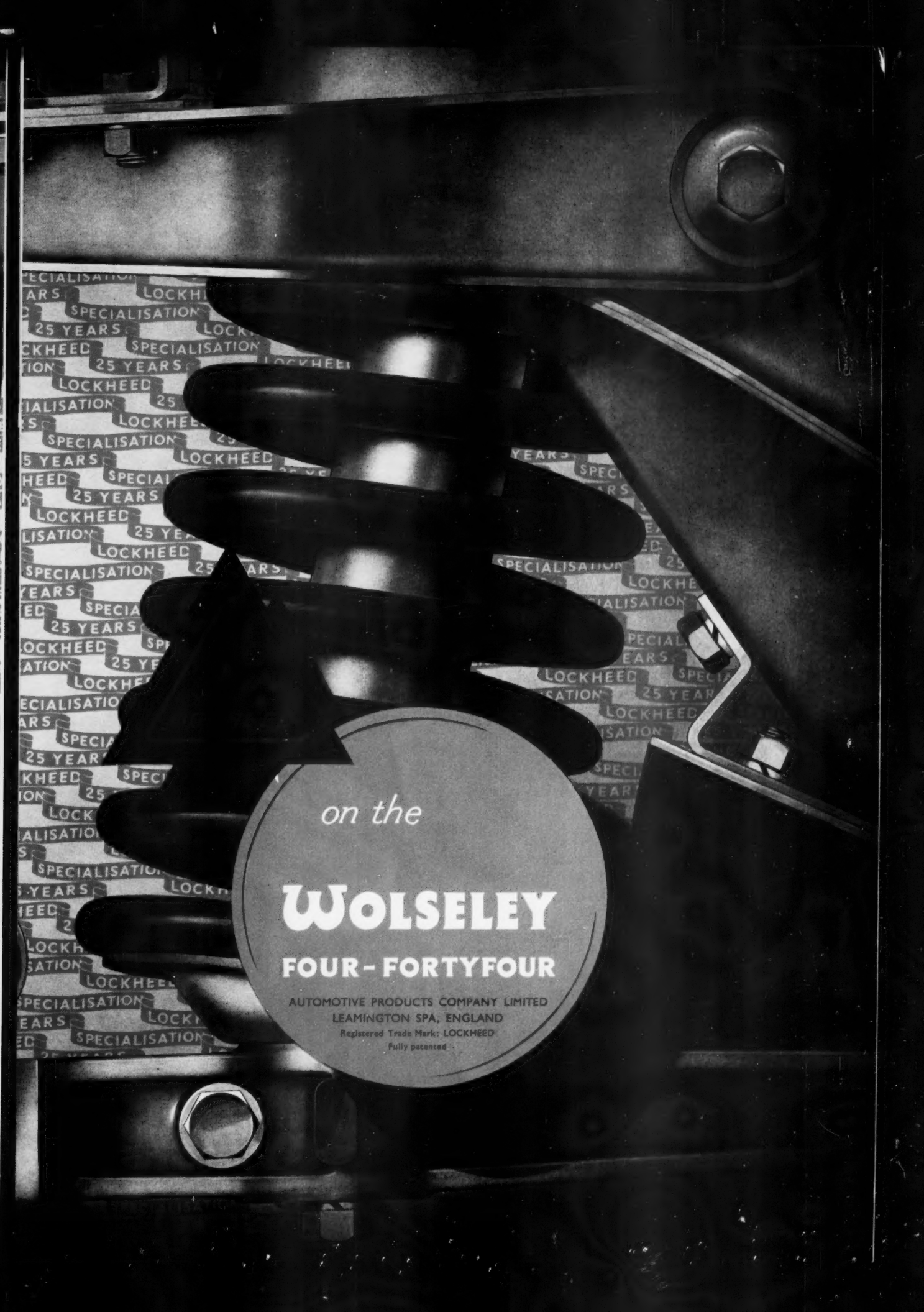
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The top illustration shows a Holman portable compressor fitted with a Rockford clutch.

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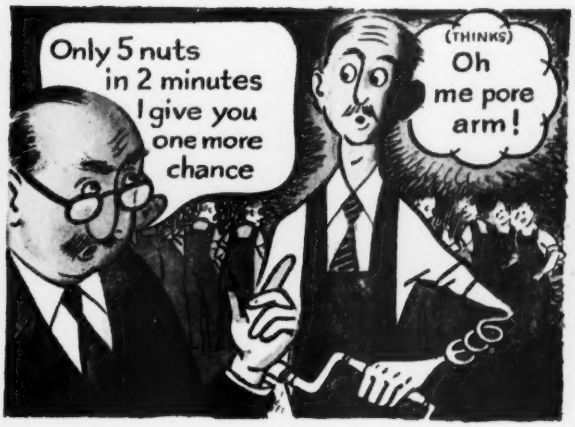

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Cliff's work is worth looking into!

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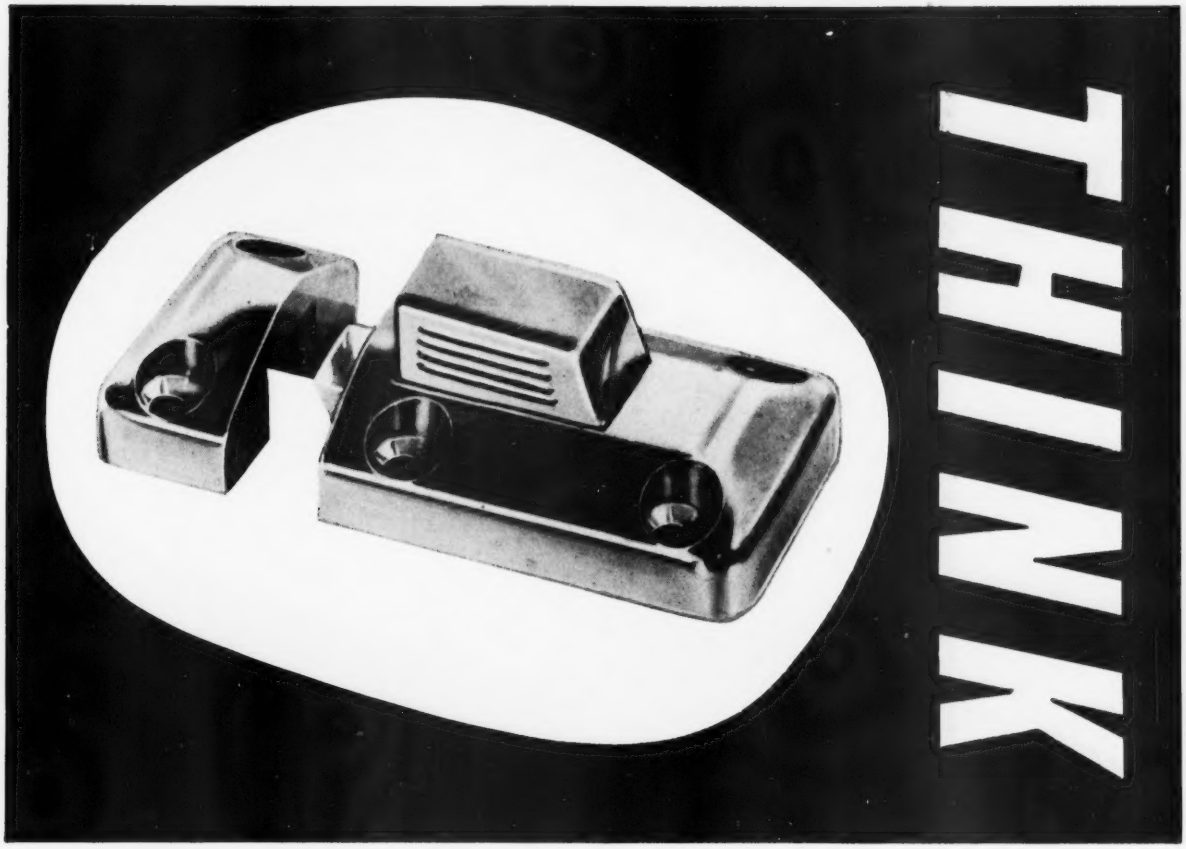
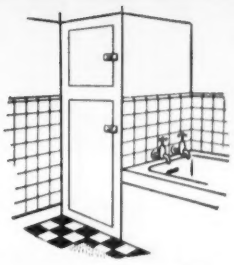


THINK ZINC



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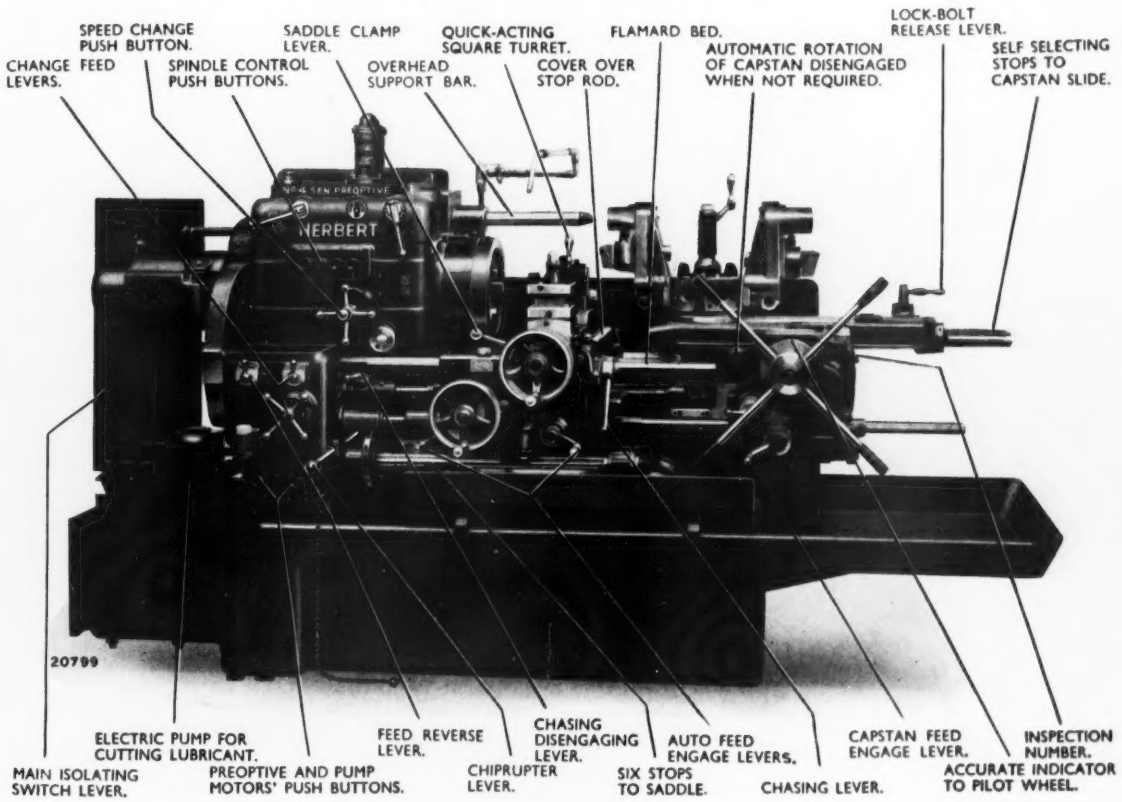

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. . ensures more positive braking, and the M.M.D. Spring Loaded Clevis Joint is the finest solution to the problems of "sloppy" brake linkage and repeated adjustment. Wear, slack and rattle on all mechanically-operated linkages can be eliminated throughout the life of the car with the aid of this rationalized clevis joint. Available to suit all requirements of the Motor Industry.

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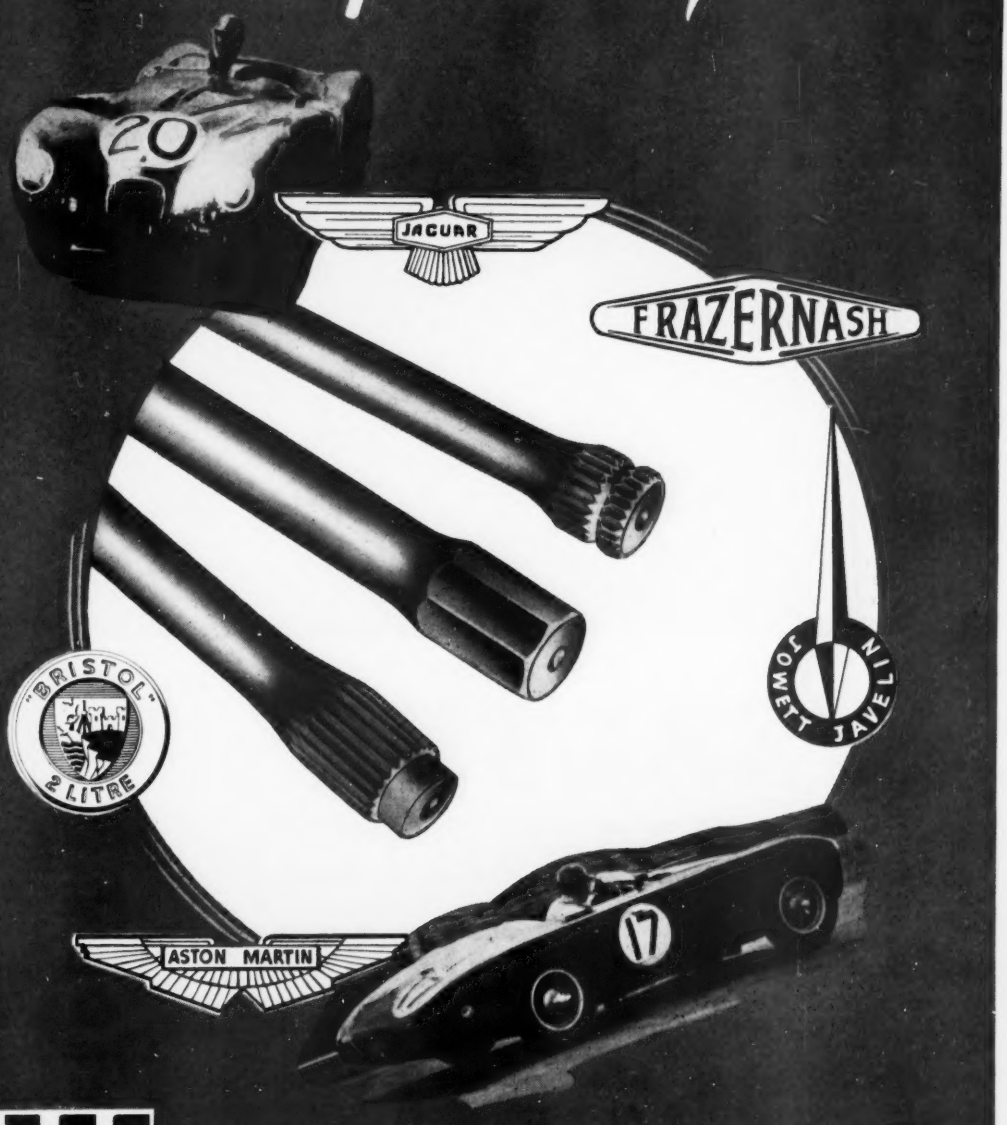
MIDLAND MECHANICAL DEVELOPMENTS LTD.

PARKER STREET WORKS · PARKER STREET · BIRMINGHAM 16

R. & W.

for the suspension systems



ESC TORSION BARS

Produced in accordance with a rigid specification based on our wide experience of forging, heat-treatment and machining procedures and designed to give the best metallurgical conditions and mechanical properties required for long life under arduous operating conditions.

Specialised modern plant is employed in all stages of manufacture and only precision ground bars of high quality steel produced entirely in our own works are used. Unmachined Torsion Bars are made for other well known makes of cars in addition to those mentioned above, and also large Torsion Bars for heavy vehicles.

ENGLISH STEEL CORPORATION LTD · SHEFFIELD

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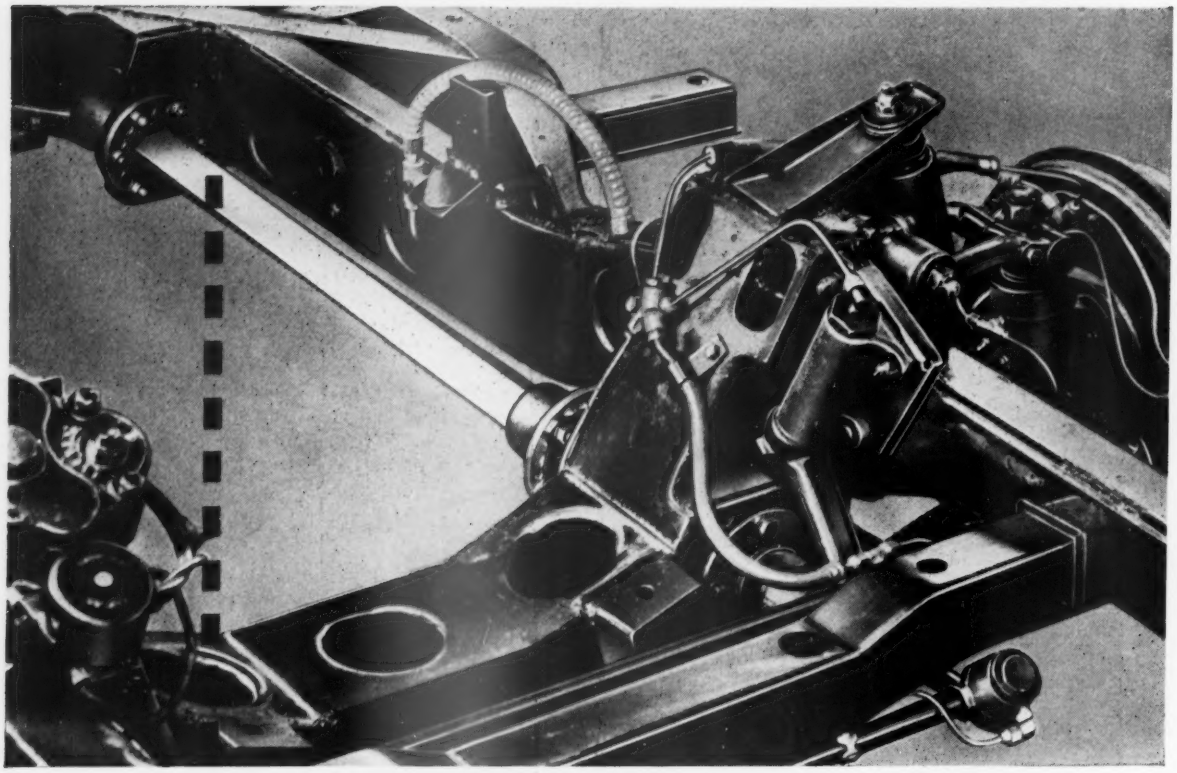


SALTER LAMINATED TORSION BARS save

SPACE — the smallest suspension unit possible

MONEY — the production process is not costly

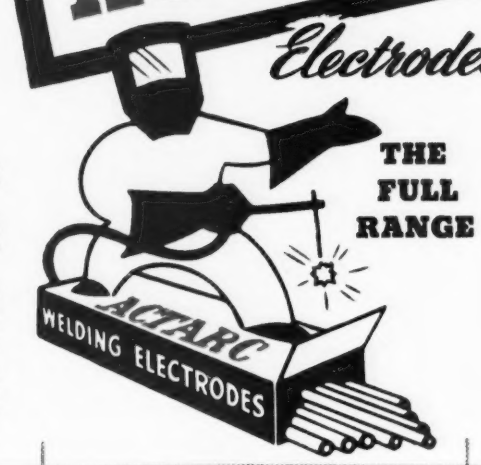
TIME — fitting to any chassis is simple

Our designers would be glad to co-operate with your development engineers as to how Salter Laminated Torsion Bars can be incorporated on your future models

GEO. SALTER & CO. LTD., WEST BROMWICH

M.W.3[illegible]

ACTARC Electrodes



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BEAMA Code E217. Easy-welding general purpose electrode.

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BEAMA Code E217. Good crack resistance and penetration, useful for badly fitting seams.

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1, 2 and 5

Low hydrogen electrodes. High impact value at sub-zero temperature.

TENSARC 1. **BEAMA Code E614.** Ideal for the hard-to-weld steels.

TENSARC 2. **BEAMA Code E614.** High tensile strength. Excellent ductility and impact value.

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1. Nickel core wire. Good machinable deposits, easy to manipulate.

2. Monel core wire—a cheaper electrode, having a machinable deposit.

3. Core wire with 55% Ni., 45% Fe. for welding nodular and other high ductility cast irons.

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BEAMA Code E317. General purpose electrode and for vertical and overhead welding. Insensitive to bad steels.

STAINLESS ELECTRODES

STAINLESS WHITE for welding molybdenum-bearing austenitic stainless steel, 18 Cr., 8 Ni., 3 Mo. type.

STAINLESS BLUE for welding Ti. or Co. stabilised 18 Cr., 8 Ni.

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BEAMA Code E217. Smooth, easy to handle. No fumes, good slag removal.

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ALUMINIUM YELLOW has 5% silicon core wire.

A general purpose electrode for aluminium alloys.

ALUMINIUM BLACK. 5% magnesium core wire. For duralumin, MG5, and similar alloys.

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The number denotes the Brinell hardness of deposit from these electrodes.

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C.A.V. Combined TAIL and STOP LAMP

In the campaign for safety on the road, increasing attention is being focussed on the need for a higher standard of rear lighting on commercial vehicles, and C.A.V. have produced a new large diameter combined rear light and stop lamp. This latest contribution to safe driving is designed for long range visibility, to eliminate failure even under the most rigorous conditions of usage, and to give ease of installation.

- 3⅝ in. red light for outstanding visibility
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- High power stop light with bulls-eye lens
- Good illumination of number plate
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- Rubber covered for protection
- Waterproof cable entry

Fully complies with S.A.E. requirements.

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BIRMINGHAM'S FAMOUS
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A new S.14 type
44 seater Public
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and for the first time in
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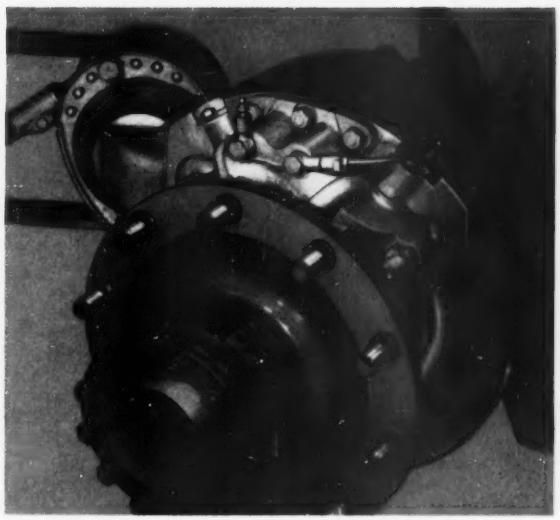

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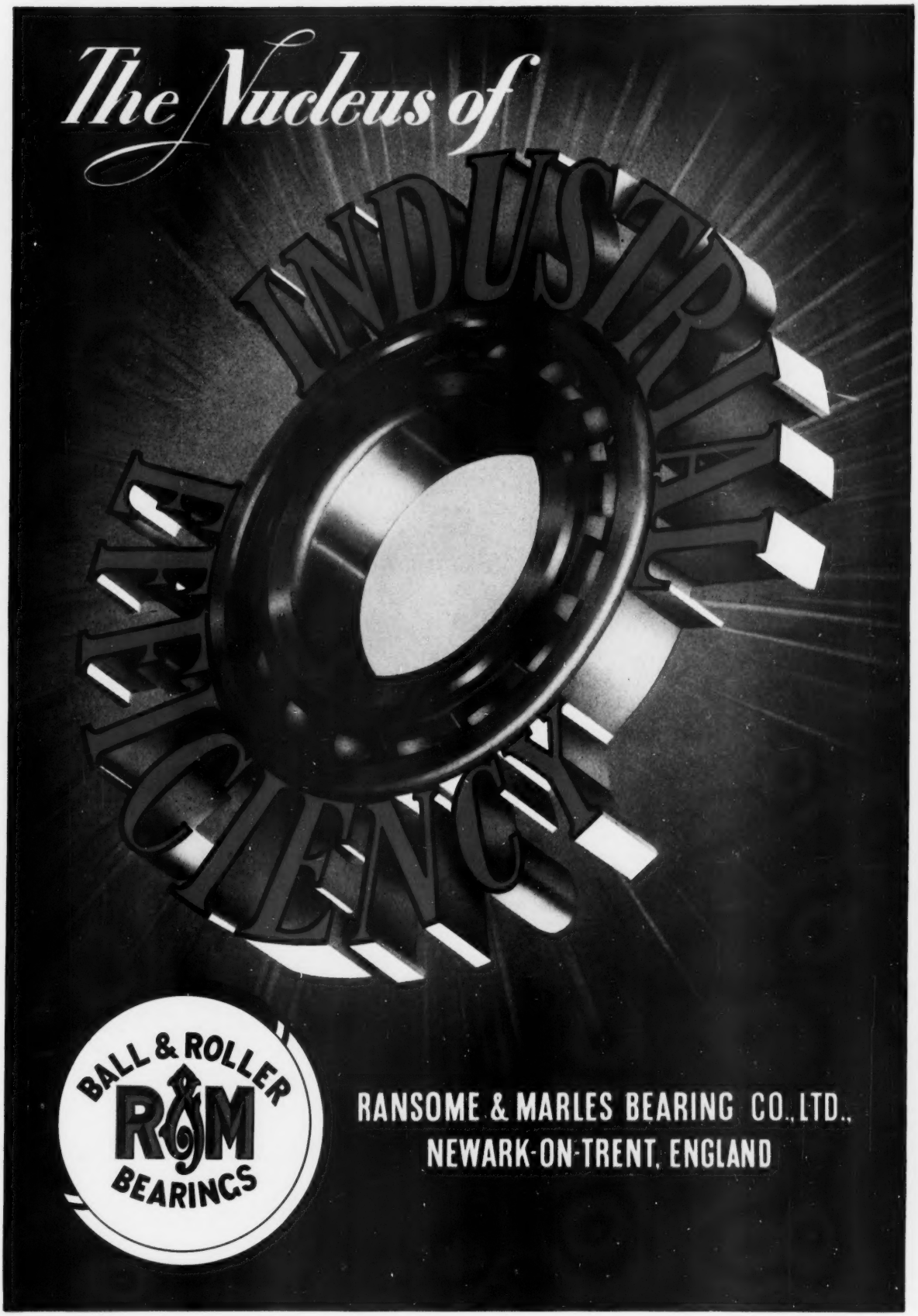
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CONCENTRATED PRESSURE

Patent application 6907/48

Proved in service, the Silentbloc-Harris Concentrated Pressure Spring Shackle is now a standard fitting on a number of popular production cars.

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improved health...

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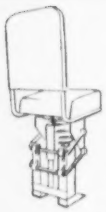
'fluid cushion'

seats



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Driving fatigue, discomfort and ill-health become things of the past when you fit Woodhead-Monroe 'fluid-cushion' seats to all sprung or unsprung vehicles, such as trucks, dumpers, locos or tractors, etc. The entire seat is supported by a spring controlled by a shock absorber, giving a ride wholly independent of vehicle movement, resulting in better nerves, easier concentration, less fatigue and greater efficiency.

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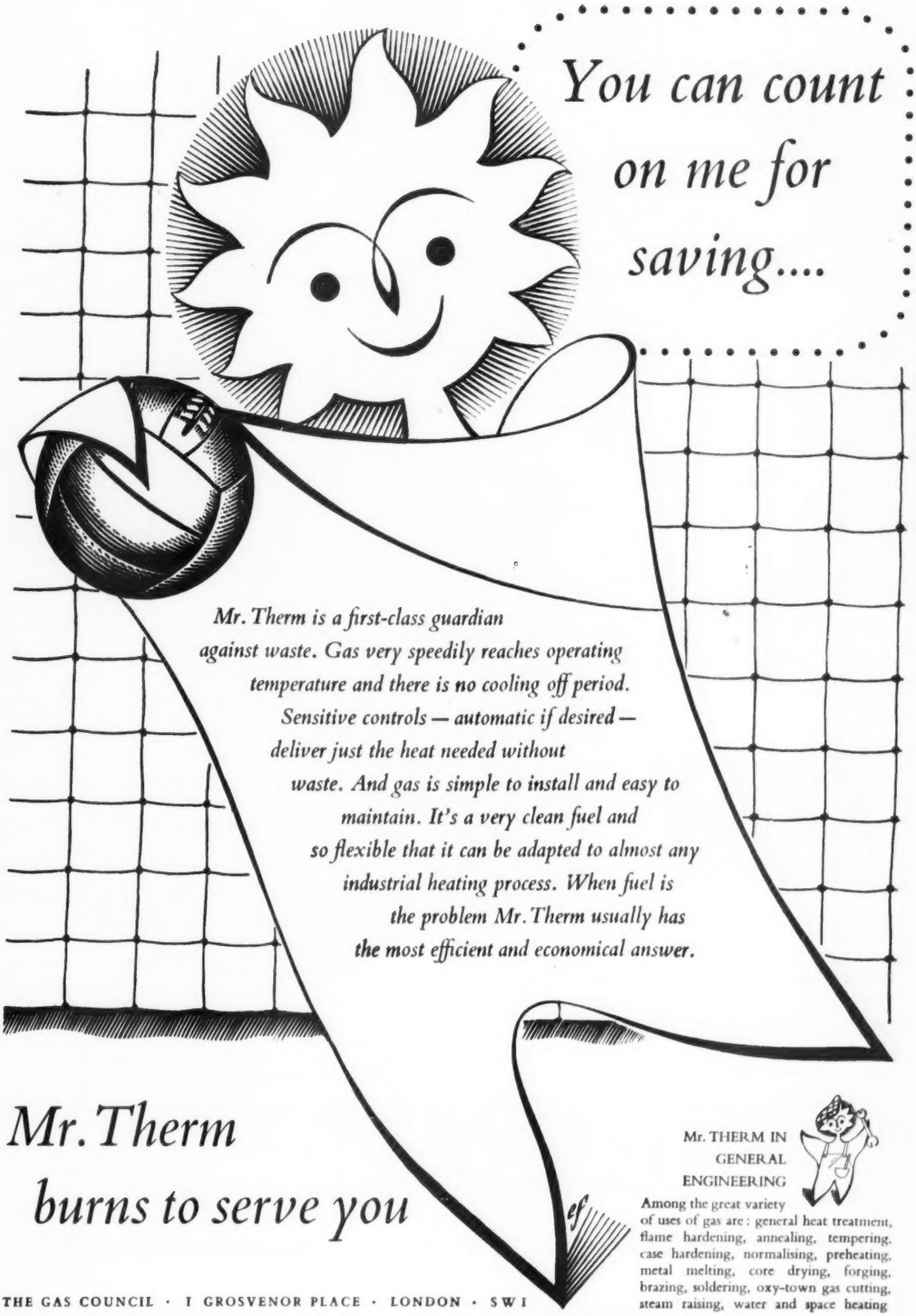
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KEIGHLEY
MODEL

KN

precision internal grinder

This graph shows the roundness of bore of a component ground on a Keighley KN internal grinding machine which was installed early in 1944. The inner circle represents inaccuracies at 1,000 x magnification and the outer circle inaccuracies at 4,000 x magnification. The workhead has not been serviced since the machine was installed and the spindle and bearings are as originally fitted, and no adjustment has been found necessary.

The KN Internal and Face grinding machine. Capacity ½" to 5½"; bores up to 6" long.

Bore Face and External Grinding on one Machine at the SAME SETTING!

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Tapered roller bearings (with detachable cones on the larger sizes).

Double bearing support to rocker shaft.

End-location adjustable.

Larger angular movement.

Very compact box.

For fore-and-aft or transverse layout.

Trunnion or spigot mounting alternative on heavy types.

THE 'MARLES' DOUBLE-ROLLER GEAR, made in a range of sizes covering every type of chassis.

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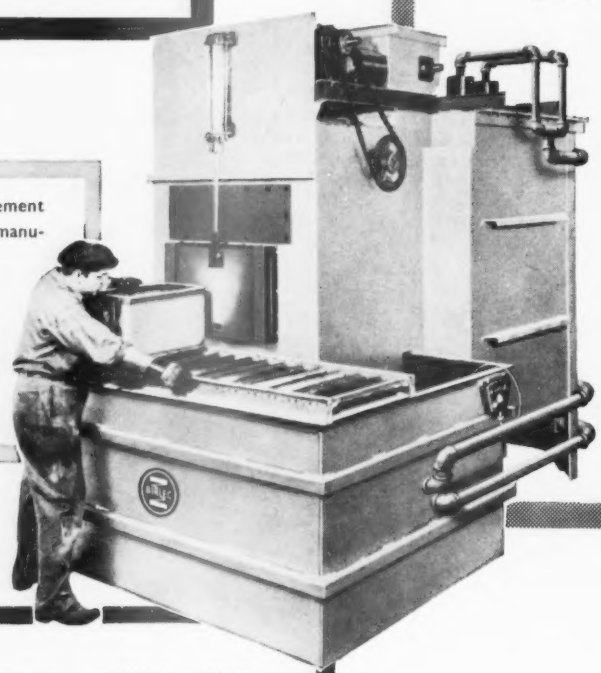
Carbo - nitriding replaces liquid cyaniding by a gaseous process, giving equivalent cases at much lower operating costs. With a greater penetration rate, lower temperatures can be used, thus reducing distortion.

The BIRLEC-DOW furnace

- ★ A gas-fired batch unit, enabling a wide range of components to be heat-treated.
- ★ Totally enclosed, heating and quenching being carried out without exposure to the air.
- ★ Built-in atmosphere generator, cutting down floor space requirements.
- ★ High heat storage efficiency, giving rapid temperature recovery with fresh charges.
- ★ Efficient atmosphere circulation, permitting dense loads of closely packed articles to be handled.
- ★ Semi-mechanised, reducing labour requirements and providing good working conditions.

By exclusive arrangement with the American manufacturing patentees, BIRLEC LIMITED have now added the DOW carbo-nitriding furnace to their wide range of heat-treatment equipment.



Standard designs are available from 250 lb. per hour (carbo-nitriding with .003" case) upwards. Full design and operating data are available; **may we send further details?**

BIRLEC

BIRLEC LIMITED

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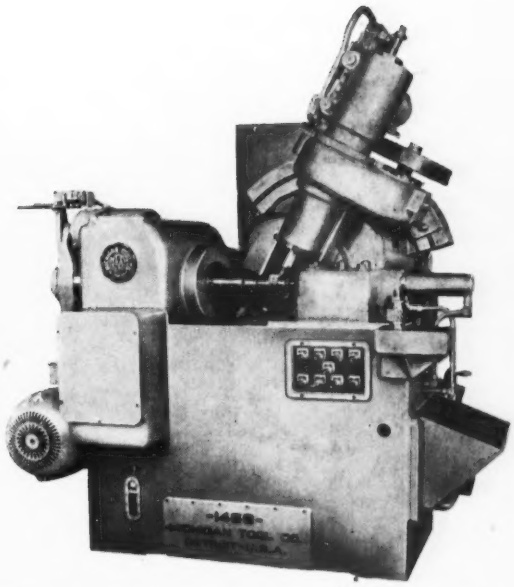
Sales and service offices in LONDON, SHEFFIELD *and* GLASGOW

The Fastest Gear Shaper in the World

The Michigan "Shear-Speed" Gear Shaper is the fastest of all precision gear cutting machines. It is ideally suited to the production of spur gears and splines, including shoulder gears.

Available in 4 sizes, for gears and splines up to 3", 5", 7" and 10" diameter, respectively.

The Fastest Single Spindle Gear Hobber



The new Michigan Single Spindle Gear Hobber closely approaches the Shear-Speed in its output rate. It is ideally suited to helical as well as spur gears and splines up to 8" diam. and 5" face.

It will cut two 3" diam. 1" face gears to well within pre-shave tolerances in 58 seconds.

We will be glad to send you complete information on either or both machine types.

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SALES AND SERVICE ENGINEERS TO:

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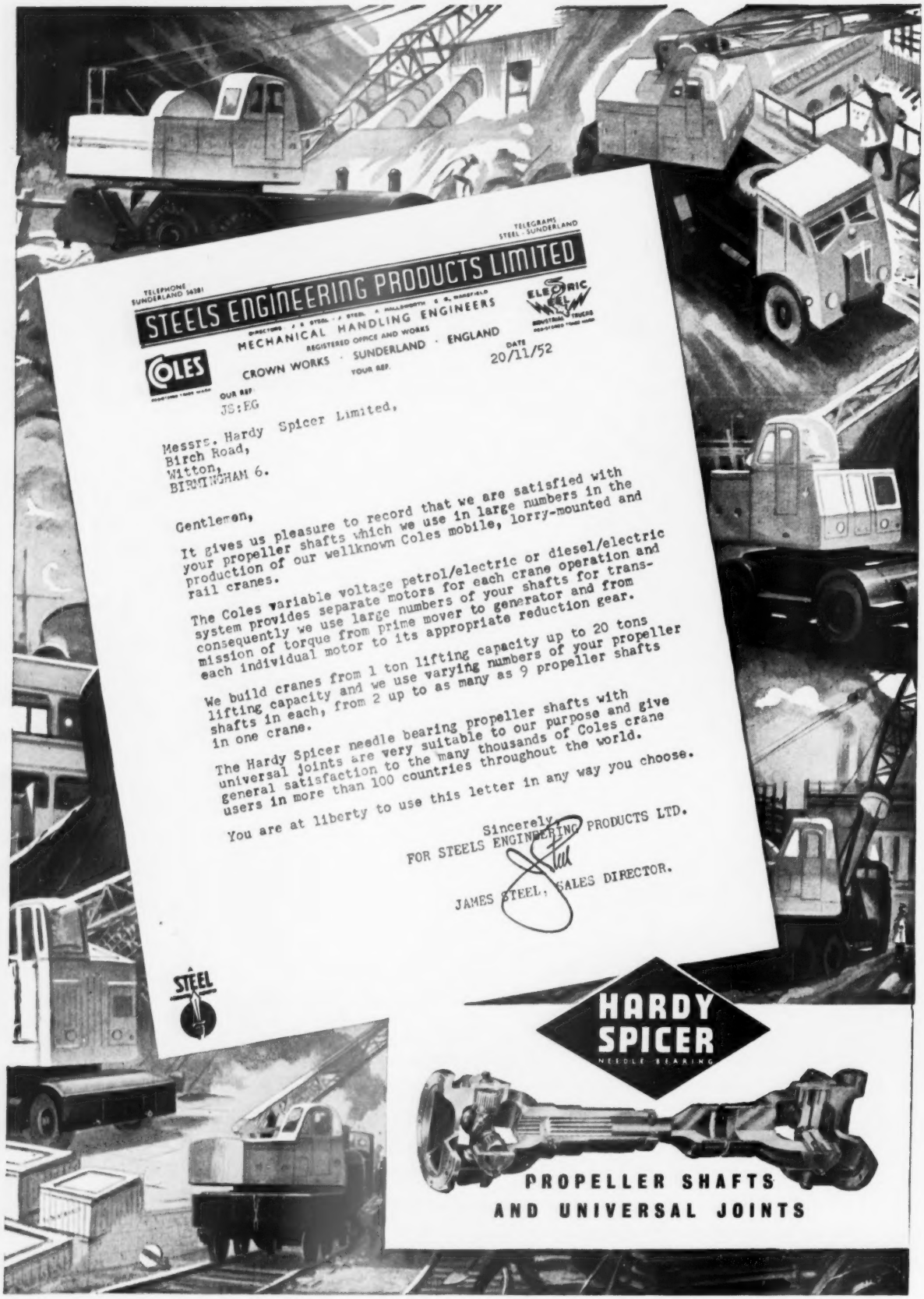
from blank to finished gear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Gentlemen,
It gives us pleasure to record that we are satisfied with your propeller shafts which we use in large numbers in the production of our wellknown Coles mobile, lorry-mounted and rail cranes.
The Coles variable voltage petrol/electric or diesel/electric system provides separate motors for each crane operation and consequently we use large numbers of your shafts for transmission of torque from prime mover to generator and from each individual motor to its appropriate reduction gear.
We build cranes from 1 ton lifting capacity up to 20 tons lifting capacity and we use varying numbers of your propeller shafts in each, from 2 up to as many as 9 propeller shafts in one crane.
The Hardy Spicer needle bearing propeller shafts with universal joints are very suitable to our purpose and give general satisfaction to the many thousands of Coles crane users in more than 100 countries throughout the world.
You are at liberty to use this letter in any way you choose.
Sincerely,
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JAMES STEEL, SALES DIRECTOR.
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HARDY SPICER
NEEDLE BEARING
PROPELLER SHAFTS
AND UNIVERSAL JOINTS

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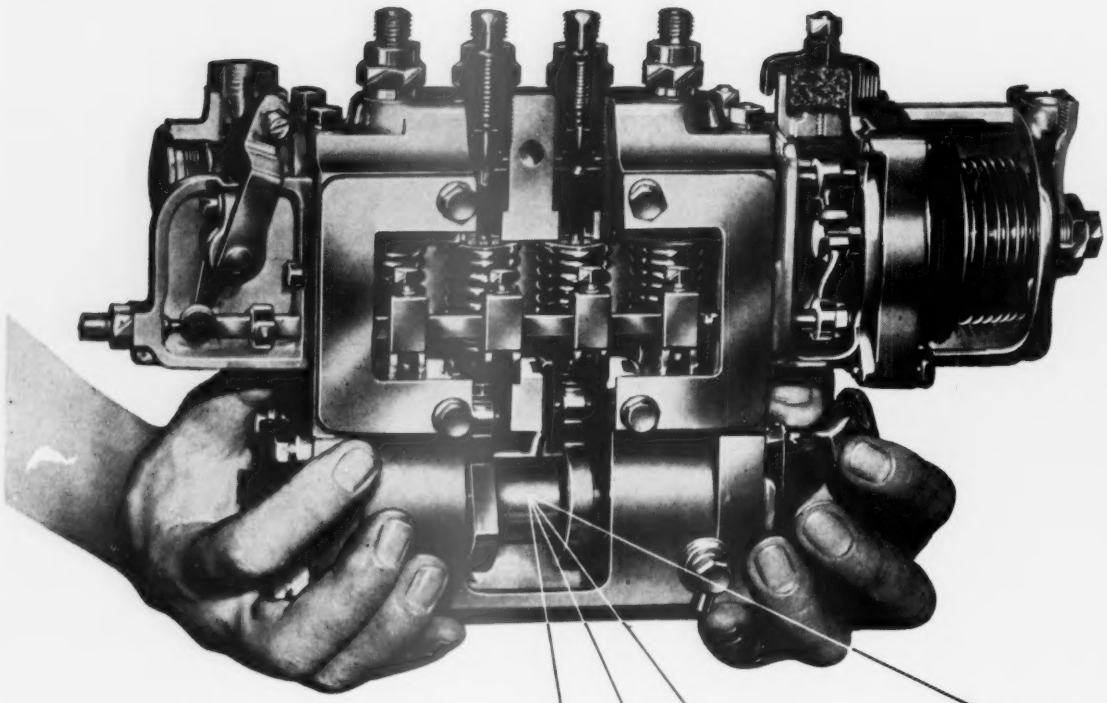
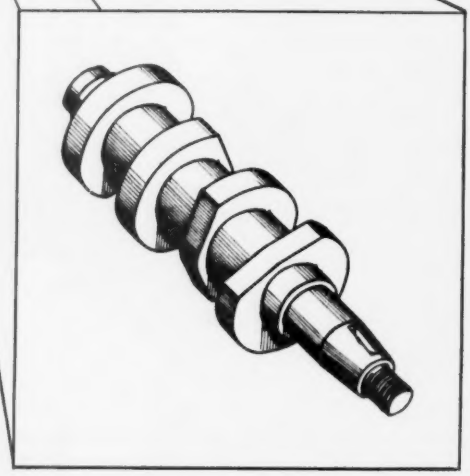
Simms *present* { the new features of their fuel pumps in detail



NEW large diameter stiff camshaft to withstand higher pressures.

Under certain conditions, it is possible to start up and run diesel engines in the opposite direction of rotation. This however, cannot happen on engines fitted with the new Simms pump, as the camshaft prevents reverse running. If the engine rotates in reverse, injection occurs at a point which will not permit combustion. The camshaft has two or three times greater stiffness than the usual pump camshaft, to resist heavy loads imposed by direct injection. These features are typical of the unique design of the new Simms fuel injection pump.



FUEL INJECTION
LIGHTING & STARTING EQUIPMENT

Simms

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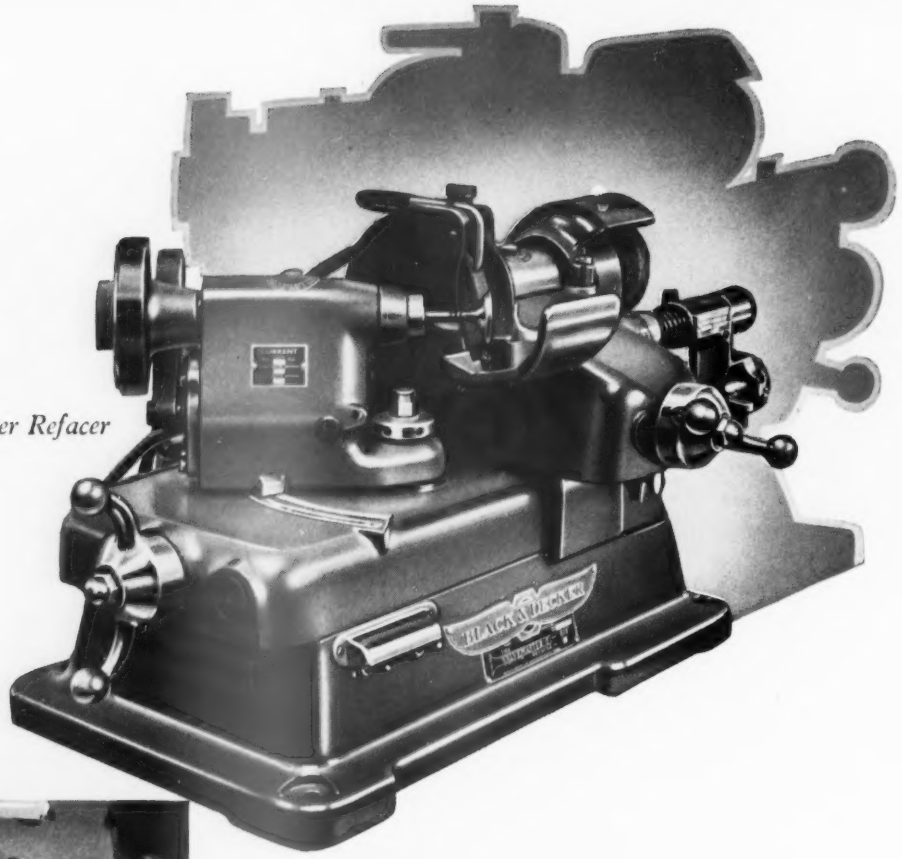
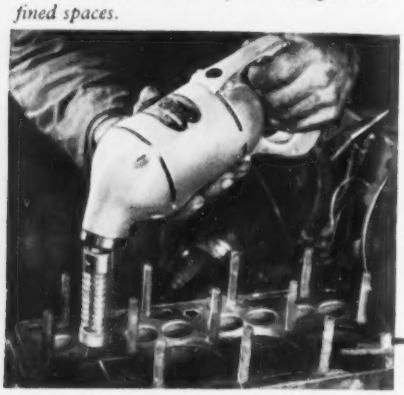


Valve Master Refacer

The B&D Valve Shop *incorporates the Valve Master Refacer, the Vibro-Centric kit and the Carbon Removing kit in a transportable cabinet.* ***The 55° Vibro-Centric*** *Valve Seat Grinder used for working in confined spaces.*



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. . . that badly matched or pitted valves destroy the smooth running of an engine . . . reduce power . . . increase petrol consumption—but DO YOU KNOW that the quickest, easiest and best way of righting all valve faults is with B&D equipment. The Valve Master Refacer refaces a set of valves to any angle with mirror-smooth finish in a matter of minutes and with an attachment grinds tappets, rocker arms and Ford Valve Stems! Its sister tool the 'Vibro Centric' valve seat grinder ensures a perfect match between valve and seat every time!

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They stay put
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Then—out they come,
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No wonder so many designers and engineers specify Unbrako!

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• MAKE GROOVE ZONE WEAR NEGLIGIBLE
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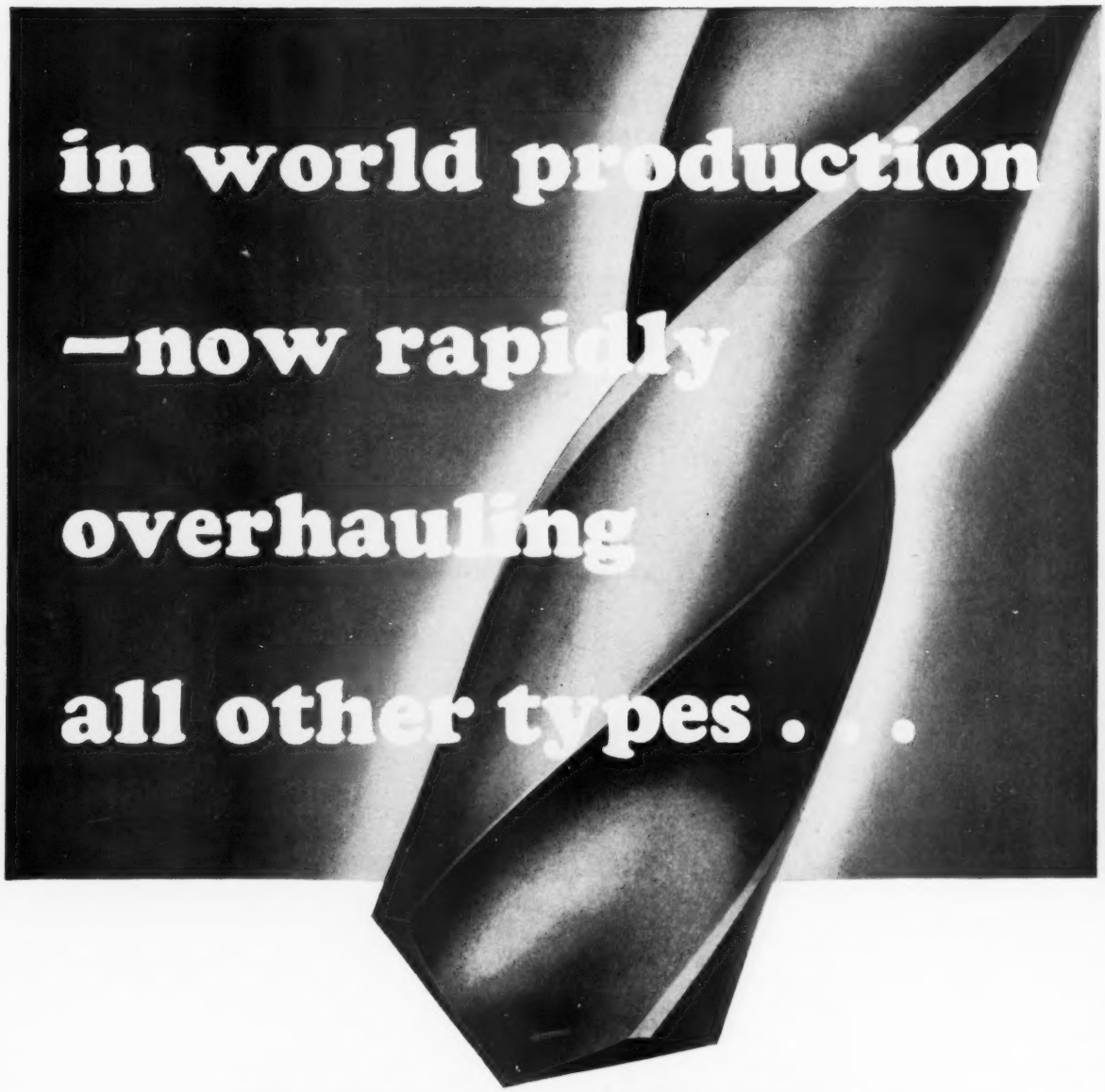

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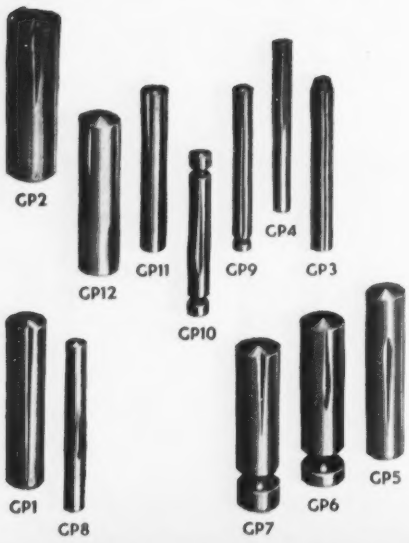

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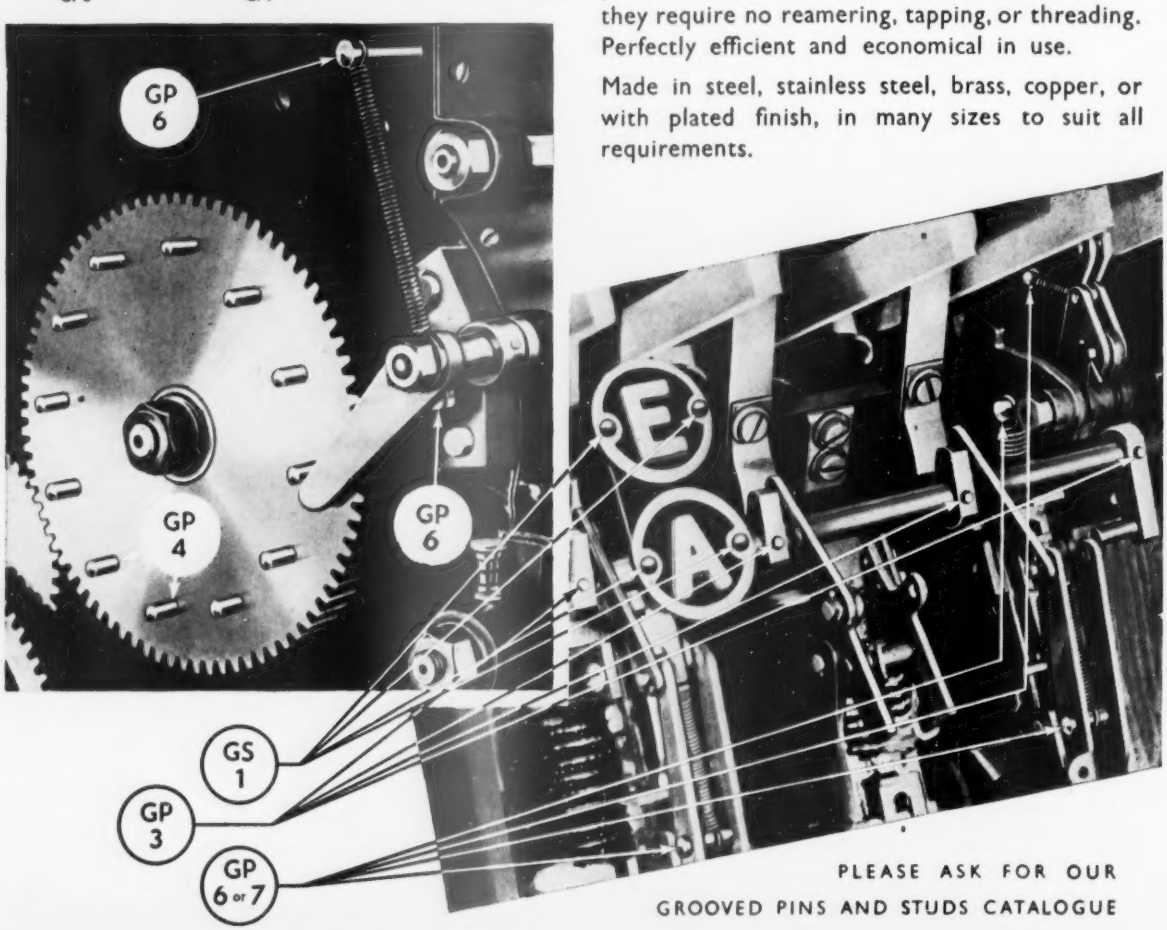

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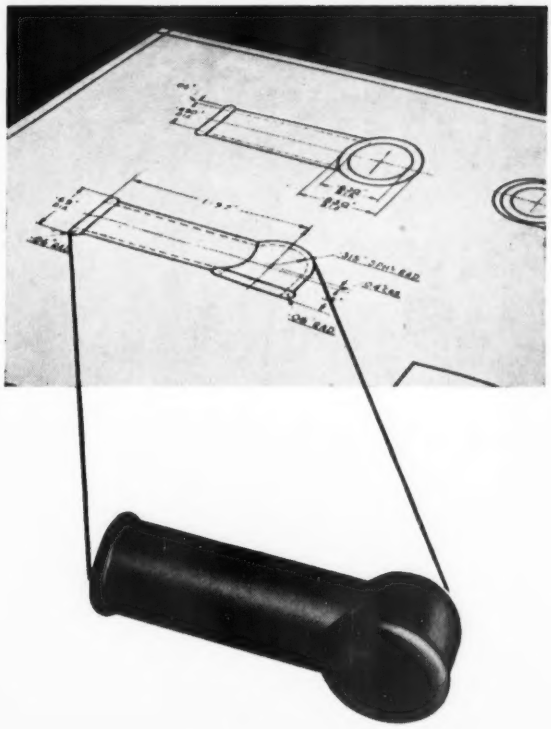

PROTOTYPE MOULDINGS *in* RUBBER

A Special Service to Industry

Experimental and development work is greatly facilitated by St. Helens' Prototype Moulding Service. Small quantities of rubber mouldings can be produced with a minimum of delay and without costly tooling, exactly to the specification of the designer.

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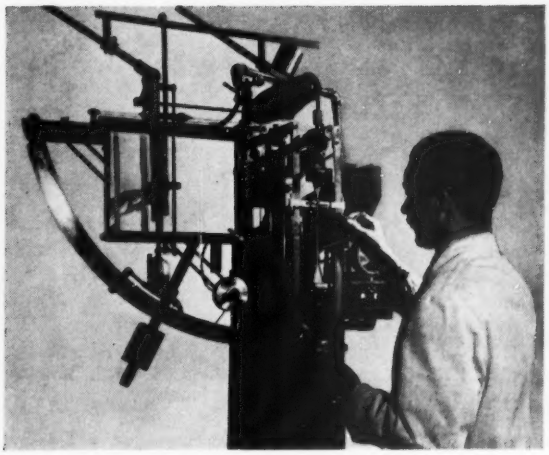

Modern research and testing methods are employed for investigating service requirements and for maintaining a uniformly high standard of production. The above apparatus is used for determining tensile strength, elongation and modulus.

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INDUSTRIAL MOULDINGS

In Natural and Synthetic Rubbers

As pioneers in Rubber Technology, St. Helens have wide experience in the progressive application of rubber in the service of industry. If you have new components in mind, or are considering the possibilities of rubber as an alternative material, your enquiries will be welcomed.

ST. HELENS CABLE & RUBBER CO., LTD.,
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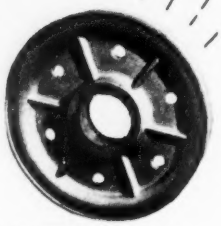
M.V. "Aureol" 14,083 g.t. built for the Elder Dempster Line.

MEEHANITE CASTINGS VERSUS THE CORRODING SEA



The sheaves and rollers of these davits made by Schat's Davits Ltd. for the Elder Dempster liner M.V. "Aureol", are cast in Meehanite metal. The choice of Meehanite metal was obvious—its anti-corrosion properties, close uniformity of grain and high strength were too important as safety factors to be ignored. With Meehanite the scientific balancing of materials and methods ensures that each casting has the precise properties required for the job. Whether you require small repetition castings or larger castings up to twenty tons, we can meet your need. Why not consult us on any of your present or future needs in castings?

QUALITY AND SERVICE

ASHMORE'S MEEHANITE

ASHMORE, BENSON, PEASE & CO

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*'Syndromic' Automatic Lubrication soon pays for itself!

*INCREASES YOUR PAYLOADS 10%

From the moment you equip your vehicle with ' Syndromic ' Lubrication it begins to pay for itself ! First, it saves up to 75% on lubrication costs. Then, it ensures less wear on bearings because it automatically lubricates up to 80 bearings (using 2 pumps) at periods controlled by mileage. As a result, maintenance and replacement time and costs are kept down to a minimum.

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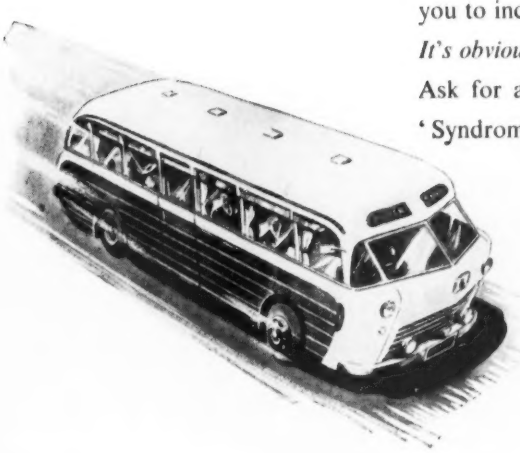
It's obvious that ' Syndromic ' lubrication soon pays for itself !

Ask for a Tecalemit technical representative to call and discuss the ' Syndromic ' system with you.



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Supplied in straight lengths from ½" o/d to 4½" o/d in gauges 22 to 6, or manipulated to your special requirements. Also available in a range of standard sections.

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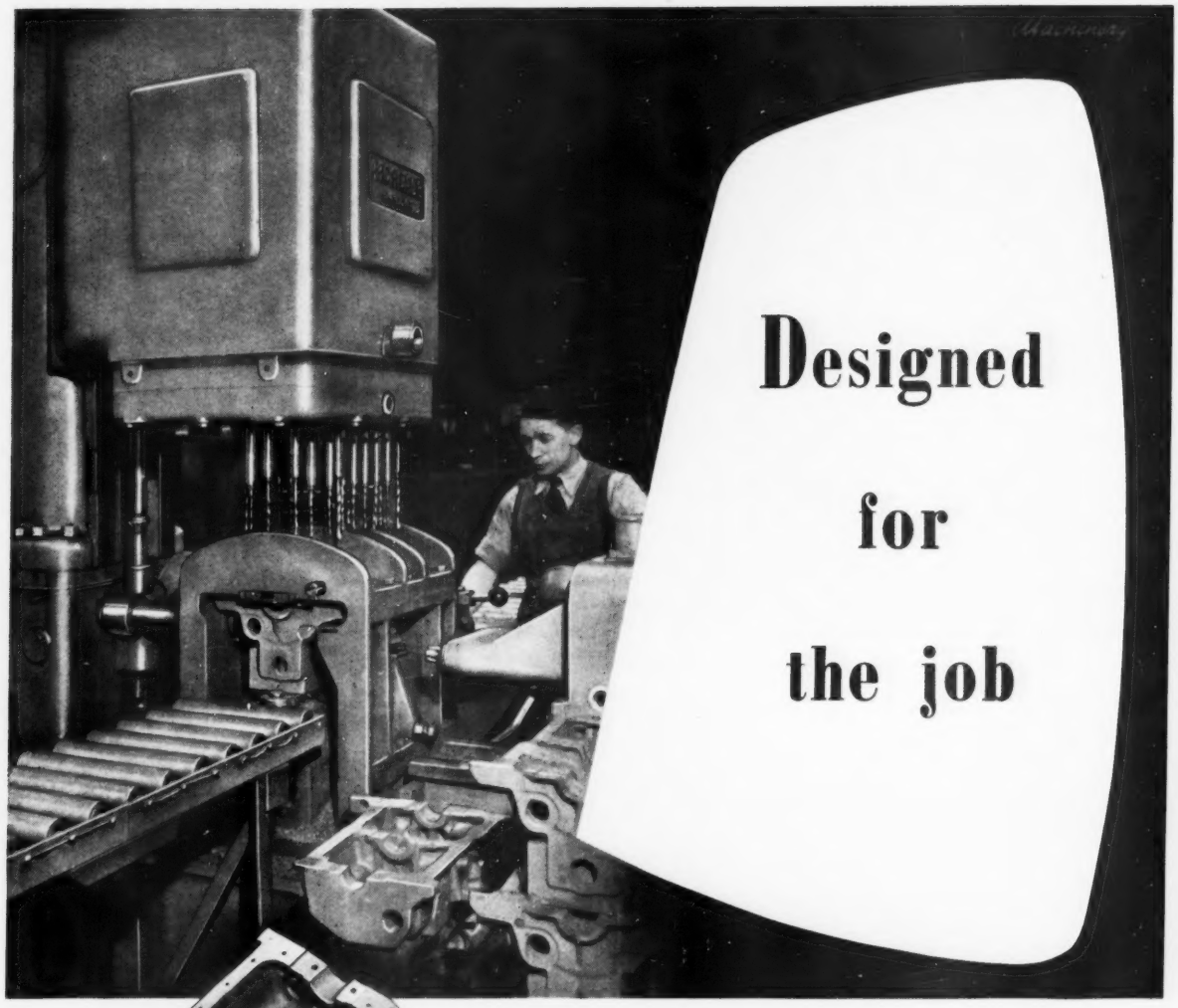
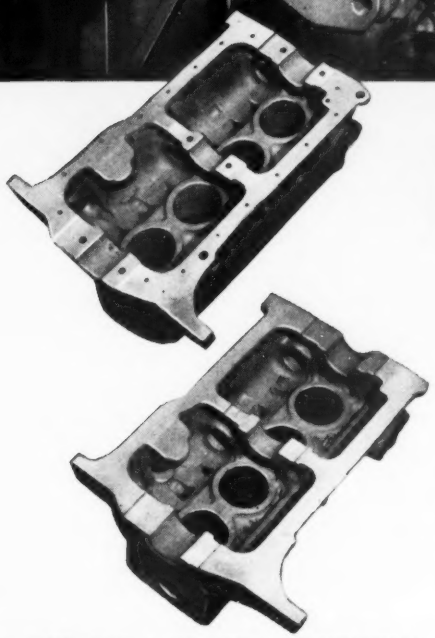


Designed for the job



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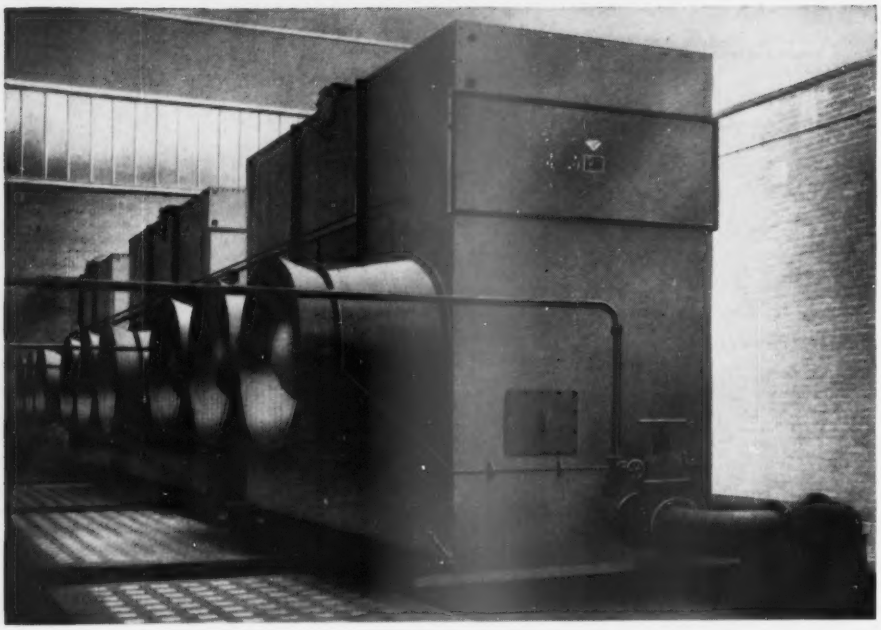

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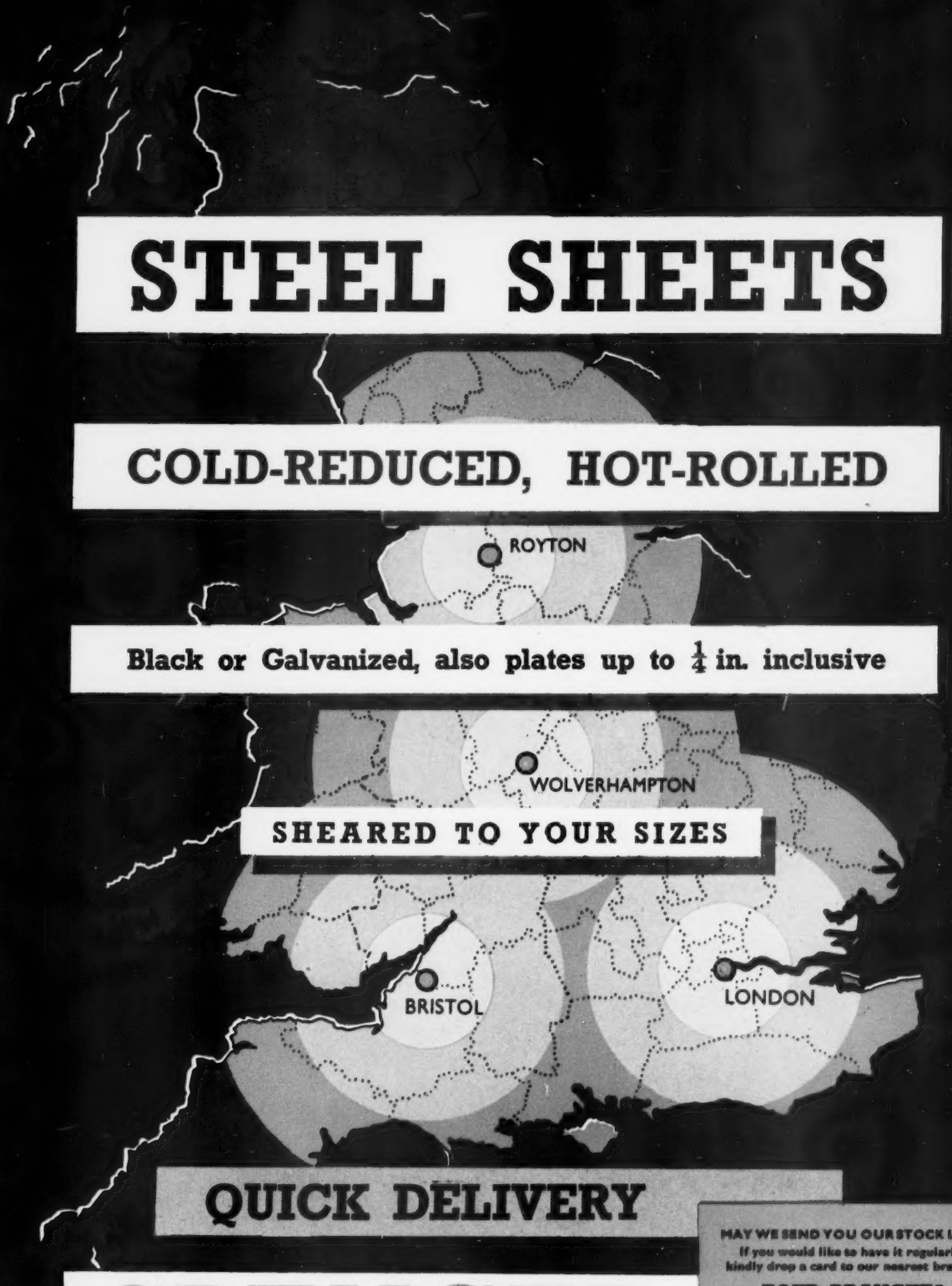

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F14

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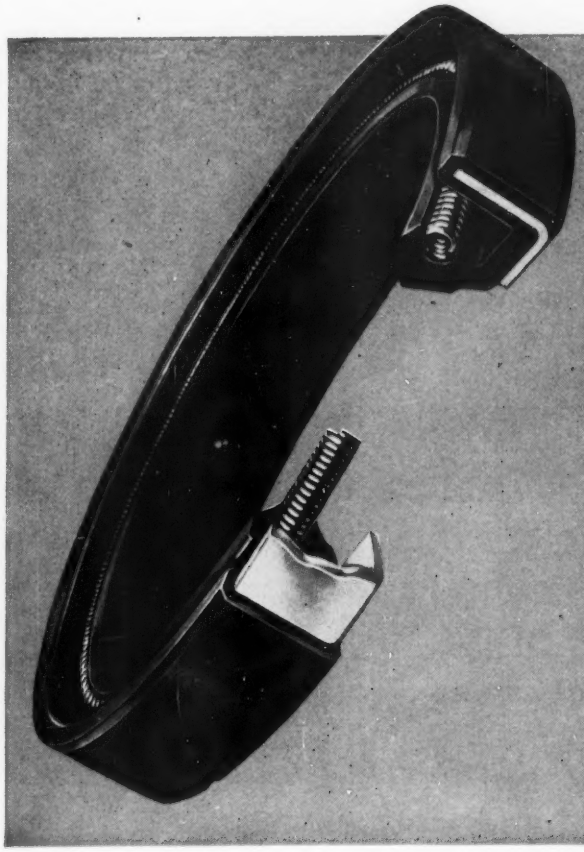
THE GACO M.I. OIL SEAL

British Patent No. 479743

The Scientifically Designed Oil Seal for Rotary Shafts. A Gaco Product.



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5. This section stiffened to prevent deformation under load.
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7. Flexible Web.
8. Gaco Skin affords better fluid tight fit in Housing.

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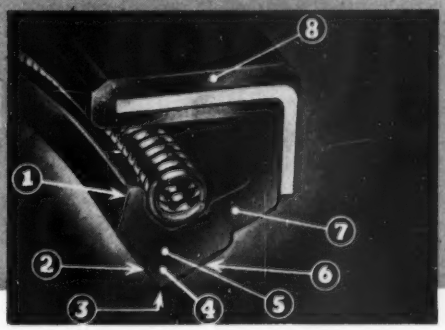

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We are now making the Metalastik Rotoflex Coupling (known on the Continent as the GIUBO)

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COMPANY LIMITED

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THE BEARING FORUM No. 5

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SELF-ALIGNING
BALL BEARING

BEARINGS

THE HOFFMANN MFG. CO. LTD., CHELMSFORD, ESSEX.

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Precision built to measure, Ferogrip Fan Belts are the choice of many leading vehicle manufacturers. Fitting components for a fine engineering job and giving a long life, their tensile strength prevents 'stretch' and ensures power transmission that is free from 'flap', 'creep' and 'slip'.

FEROGRIP FAN BELTS

Manufactured by

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Ceaselessly maintaining, and ever striving to raise even *their* standards of quality and service, and constantly keeping abreast of new trends, Linread have always been most actively concerned with the development of Cold Forging. By retaining the grain flow, Cold Forging increases the strength of the finished product and cuts production costs by showing a raw material saving of up to 70 /. And today's toolmaking methods result in a degree of accuracy once considered impossible by this process. Apart from a standard range of precision-made parts, Linread specialists are accustomed to co-operating with manufacturers at the outset to produce special cold forgings to their individual requirements.

Linread

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Confidence in Romet Water Pump Seals has been built up over the years by their unfailing dependability under every condition. Be it in the extreme cold of the Arctic, the tropical heat of the desert, or the rigours of high-speed driving, the Romet Seal performs its duty without trouble.

A SUPERFECT PRODUCT

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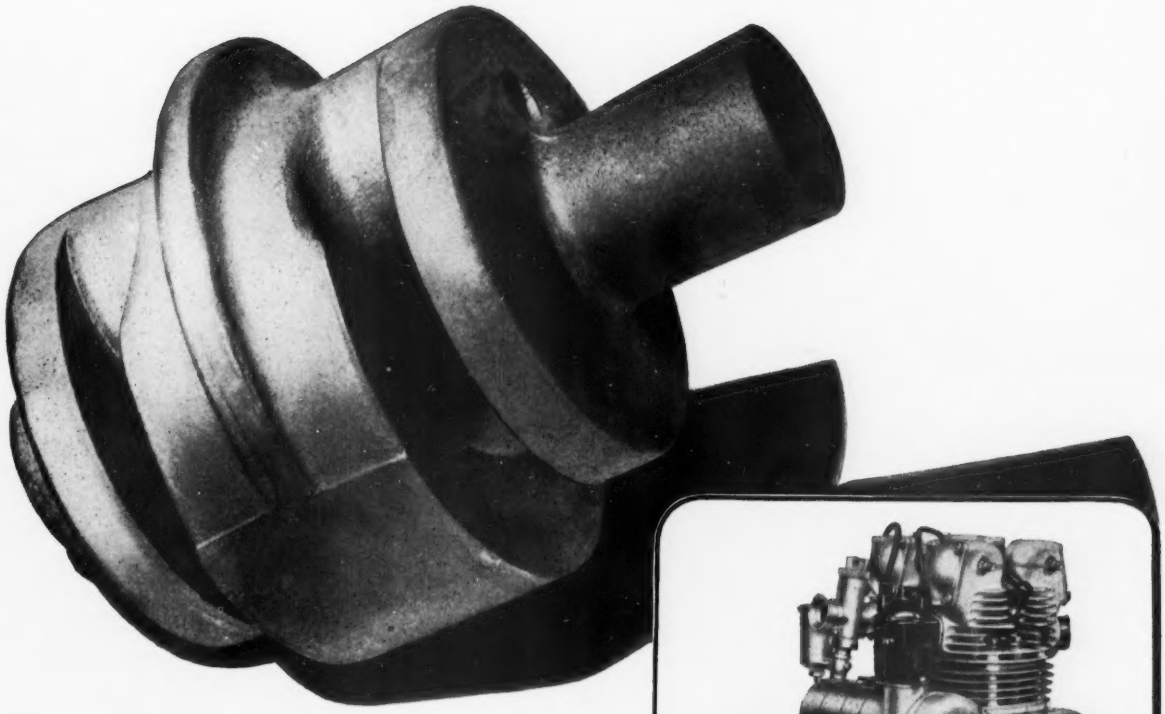
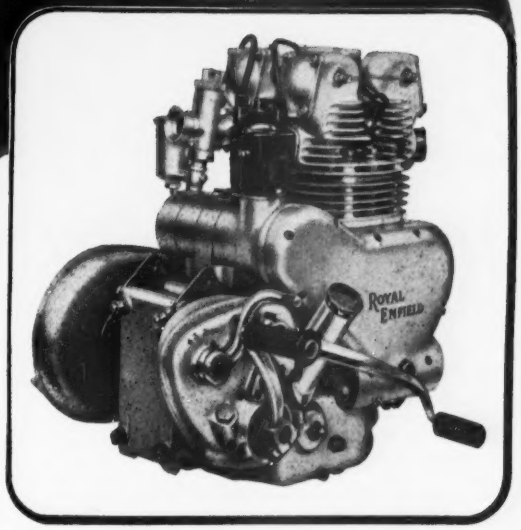
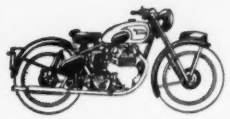
Royal Enfield are making sure with HARPER quality







The engine of the Royal Enfield "500 Twin" motor-cycle in standard trim develops 25 B.H.P. at 5,750 R.P.M. and can reach 7,000 R.P.M. The crankshaft is a Harper casting. The Enfield Cycle Co. Ltd. say: "The excellent machining properties of the material, together with its mono-bloc construction, make this a much simpler production proposition than a built-up crankshaft, besides ensuring that it runs dead true at all times."

Harper quality covers iron castings, and also metal pressings, machining, enamelling and other finishes and sub-assembly work.

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Add highly competitive initial cost, low running cost, outstanding ease of installation and maintenance; you will understand why so many in every trade and profession praise G.E.C. fittings as the ideal answer to their fluorescent lighting problems.

For the best results always use Osram tubes.

Economical to buy and operate

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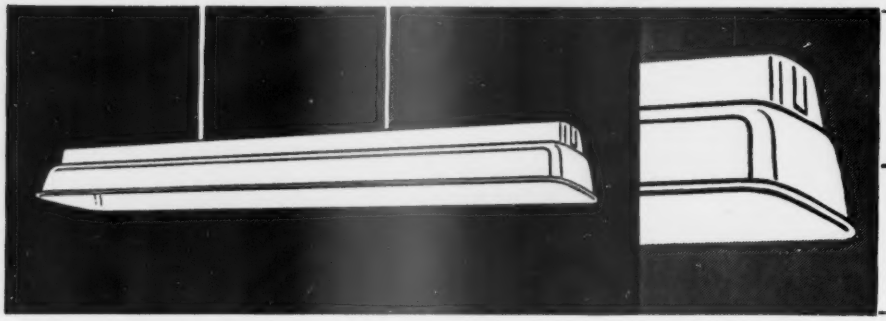

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Designed for efficiency

The reflector is pressed in one piece, free from welded joints, the ends are pleasantly rounded in shape and easy to clean. Louvred slots are pierced in the reflector to give upward light and avoid tunnel effect.

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The assembly has been planned so that the parts of any installation can be detached or replaced with ease by one man without an assistant.

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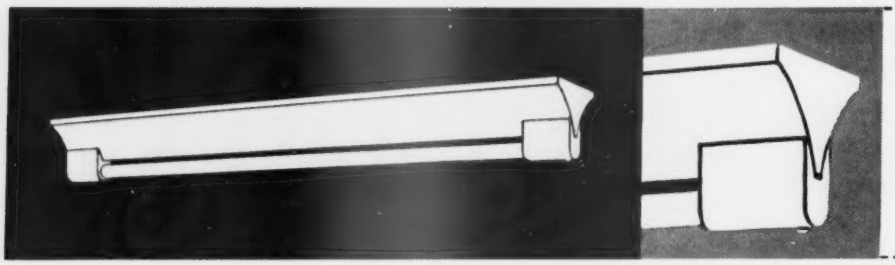
The top chassis containing the control gear may be suspended in three ways :

(a) From conduit suspensions straight into the fitting at 24" centres
(b) By conduit or chain at any suspension centres
(c) By screwing direct to the ceiling



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Finished in white stove enamel on steel. Of specially neat shape and clean appearance. Normally screwed direct to ceiling. Each end is provided with a knock-out to allow surface conduit to enter.

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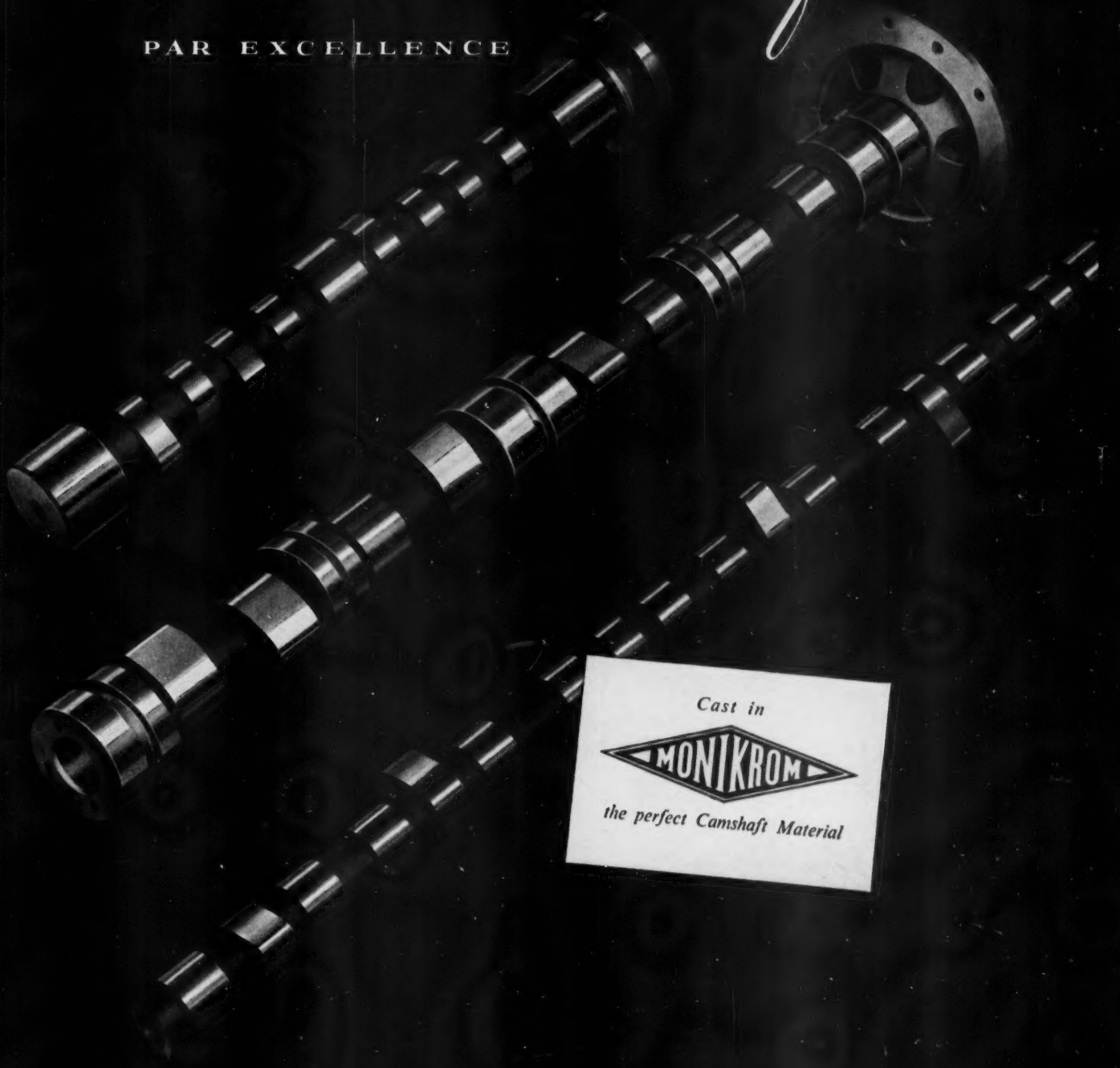

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the perfect Camshaft Material

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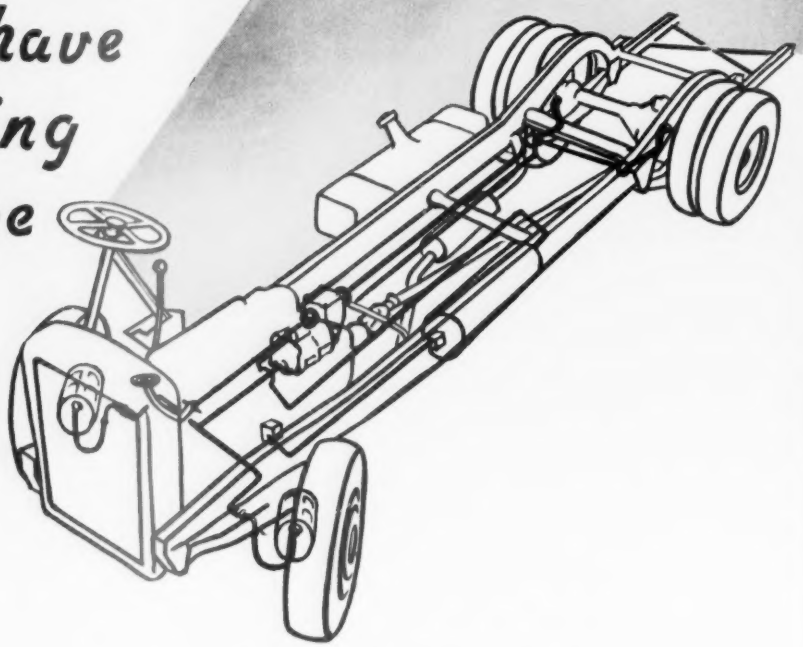

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Simplicity of layout makes installation costs small.
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Ease of obtaining correct braking ratio between front and rear axles.
In the event of rear wheel braking failure, front wheel braking is still effective or vice versa with manual braking available at all times.
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Easy replacement of units.
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VACUUM, AIR PRESSURE or CONTINUOUS FLOW.

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T.B.I.

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The Macdougalls are descended from Somerled of the Isles through whom they obtained their lands of Lorn. In the 13th and 14th centuries they became the bitter enemies of Robert the Bruce. In one battle with the Macdougalls, Bruce is alleged to have escaped only by discarding his cloak with his brooch which afterwards became known as the Brooch of Lorn, and is now a treasured possession of the Chief. The story has a modern sequel. In 1842 when the young Queen Victoria was sailing in the Royal Barge on Loch Tay, it was pointed out to her that the steersman, Captain Macdougall, was wearing this famous brooch, and Her Majesty examined it with great interest. Later at the Glasgow Exhibition in 1911, a half size copy in gold was presented to H.R.H. The Duchess of Connaught.

Motto: "Vincere vel mori"
(Conquest or death)

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Latest designs of mains frequency core type

Induction Melting Furnaces

for normal and special irons

The furnace can melt cold charges or be fed with molten metal previously melted in a cupola. In either case, alloying additions can be made to produce high duty irons, the mechanical motion of the bath ensuring complete alloying and homogeneity of product. The furnaces are particularly suitable for thin wall castings (automobile cylinder blocks, etc.).

For Normal and Special Cast Irons, standard G.W.B.—A. Tagliaferri Furnaces give an output of 140 to 2,000 lbs. per hour. Other data of their performance in relation to cast irons are shown in the panel alongside.

Among the many advantages of the

GWB-A.TAGLIAFERRI furnaces

Melting Furnaces for Normal and Special Cast Irons

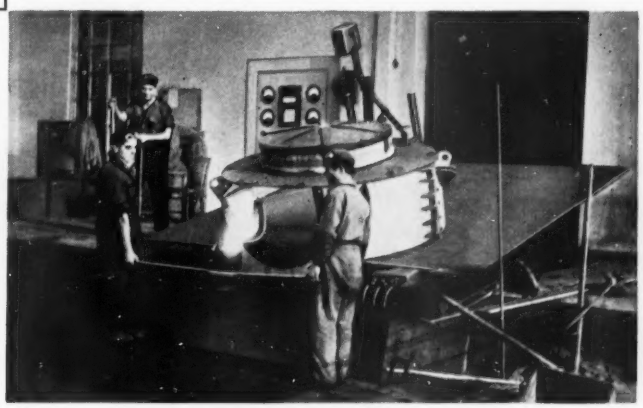
TYPE	G 50	G 100	G 150	G 200	G 300	G 400	G 500
CAPACITY LBS. TOTAL	550	990	1760	3300	4400	6600	11000
CAPACITY LBS. USEFUL	440	770	1320	2200	3300	4840	8800
RATING kW	37.5	75	110	150	225	300	450
RATING kVA	50	100	150	200	300	400	550
OUTPUT LBS. PER HR.	143	286	396	660	990	1430	1980
CONSUMPTION kWH/TON	558	558	538	508	478	467	437
TILTING METHOD	Hand	Hand	Hydr	Hydr	Hydr	Hydr	Hydr
HOW CONNECTED	1 Phase	1 Phase	1 Phase	3/2 Phase	3/2 Phase	3/2 Phase	3 Phase

The above figures which are for cold metal charges are not binding and will vary according to the product and the quality of the metal charged.

are the following :-

1. Initial starting without using hot metal.
2. Positive metal circulation without turbulence gives maximum refractory life.
3. The refractory lined casing is easily exchanged with the relined spare without removing electrical connections or inductors.
4. Clear indication is given when end of lining life is approaching.
5. Refractory lining of melting duct can be repaired without dismantling the furnace.

Full details of standard units suitable for all normal foundry requirements may be had on request.



Two model G.400 induction furnaces, supplying molten cast-iron to a foundry manufacturing motor-car parts.

Proprietors:
Gibbons Bros. Ltd.,
& Wild-Barfield Electric Furnaces Ltd.

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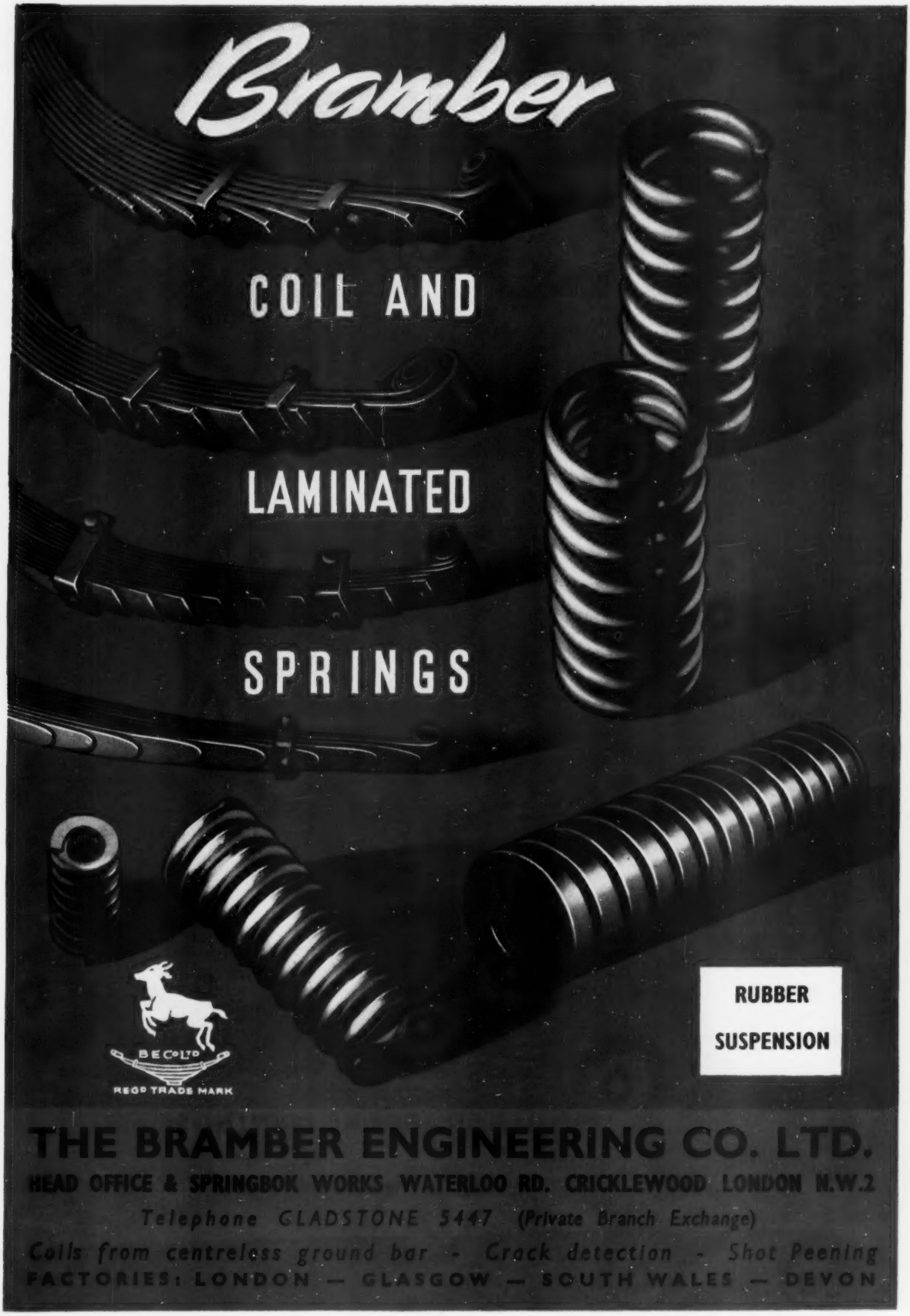
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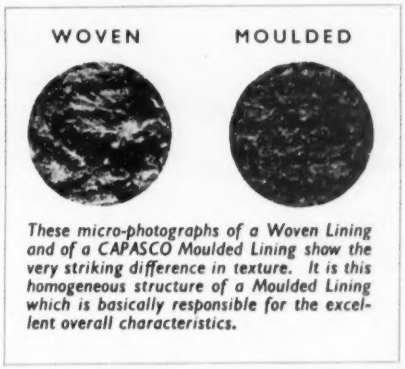

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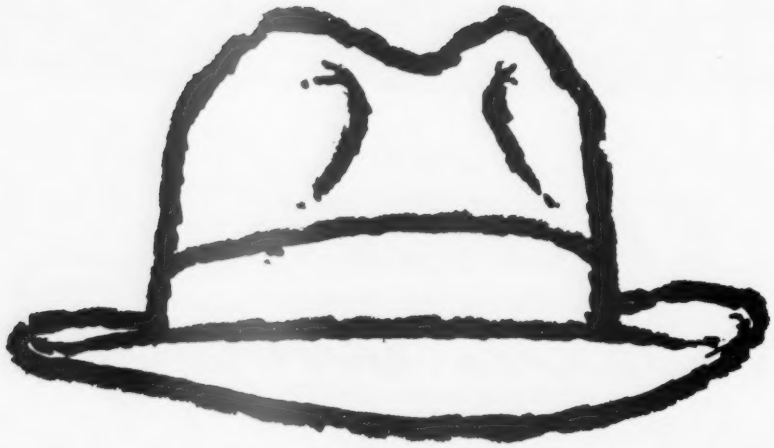

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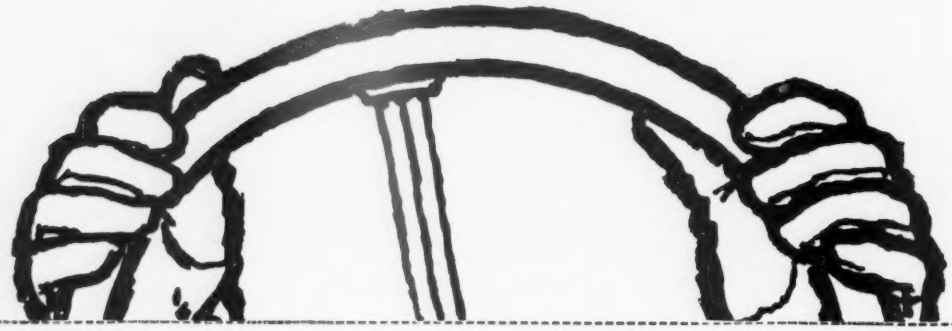

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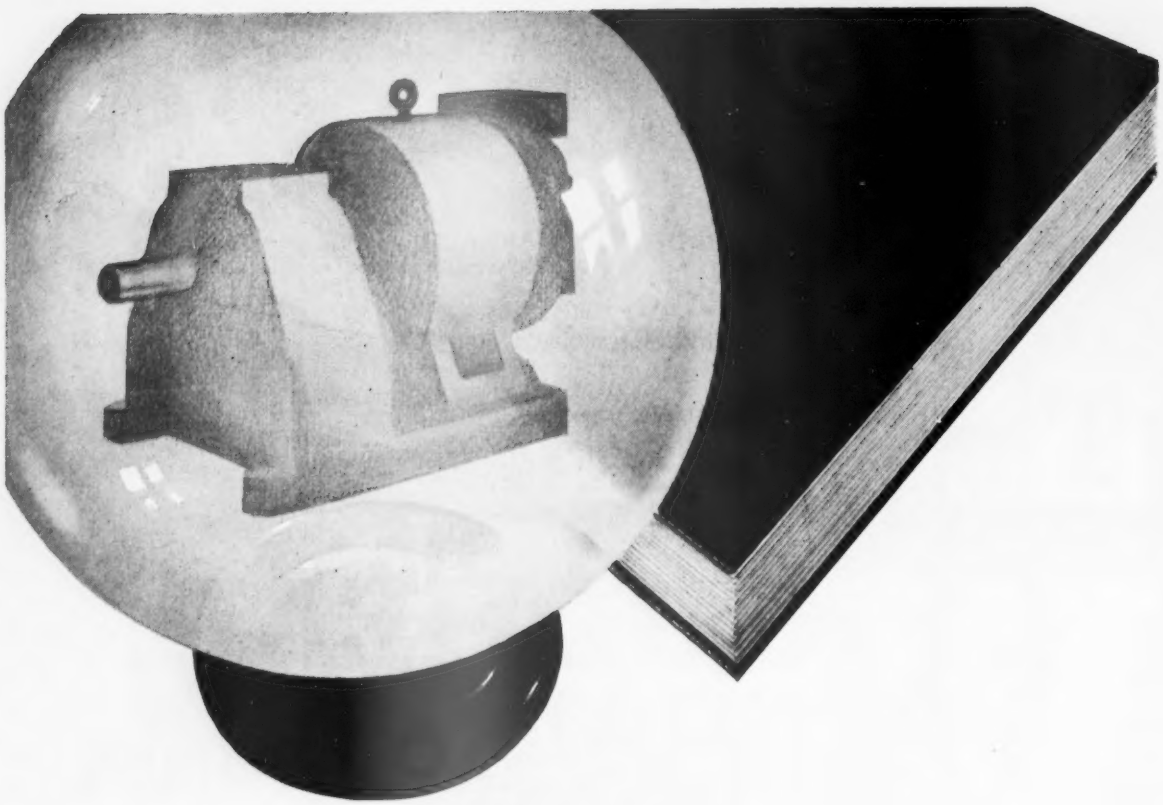

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AUTOMOBILE ENGINEER

Design, Materials, Production Methods, and Works Equipment

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Paris

ALTHOUGH at first sight there may have appeared to be little at the Paris Show, except the new Panhard Dyna 54 and Mercedes Benz 180, to interest those who went mainly to see the quantity-produced cars, there was in fact much technical detail worthy of note. Of course, modifications to models that have been in production for some time are frequently effected to meet changes in public taste or, alternatively, they are intended to remedy one or another of those obscure shortcomings of design that so often are only revealed after some years in service. In both cases, they are of interest to designers. The changes in the Renault 4 CV are of particular significance in these respects and are commented upon in the article on the Paris Show.

Aluminium

That the manufacturers of the Dyna 54, after some years of experience with aluminium, have again made extensive use of it in their latest model is a sure indication that cars fabricated from this material are a sound economic proposition. The principal advantages to be gained from the employment of light alloys are, of course, low weight and good resistance to corrosion. On the other hand, the main disadvantages are poor elongation figures relative to those of body steel, increased welding and initial costs and low fatigue strength. However, by designing for the material, rather than by trying to reproduce a steel body design in aluminium, these disadvantages can be to a large extent offset.

Secondary economies acruing from the use of light-weight materials include the possibility of employing a smaller engine, which is still adequate to give satisfactory acceleration figures. However, acceleration is only one of two criteria governing power output requirements. The other is the maximum speed to be attained. At the fairly high speeds demanded of modern cars, air resistance absorbs a large proportion of the power developed. Therefore, where economy in engine size is achieved by the use of light alloys, it is desirable, if not essential, also to make a corresponding reduction in the drag coefficient of the body. This aspect of the problem appears to have been given due attention by the manufacturers.

By incorporating a power unit of relatively high specific output, it has been possible to adopt a horizontally opposed, twin-cylinder air-cooled layout. The compactness and light weight of this engine have in turn led to a general lightening of the structure needed to support it, and have made possible the adoption of an acceptable front-wheel drive arrangement, with a further saving in space and weight. Light weight and low drag naturally lead to economy in fuel consumption.

Suspension

In the majority of cars, the front passengers are somewhere near the centre of gravity of the vehicle, while those at the back are, of course, not far from the rear wheels. As a result, there is a marked difference between the rear wheel reaction in the fully laden state and that obtained when only the driver is being carried. This situation calls for a variable rate rear suspension, and the need is particularly great when a large amount of luggage is carried in the boot.

When the ratio of laden to unladen weight is high, as in the Dyna 54, the suspension problem is even more acute. The method employed in this vehicle, of using very large rubber bump stops as auxiliary springs, has much to commend it, especially from the point of view of simplicity. A number of variable-rate suspension systems are in use on quantity-produced cars of Continental manufacture, notably the Grégoire suspension, that of the Citroen 2 CV, and the adjustable auxiliary torsion bar that has for many years been a feature of the rear suspension of the Mercedes Benz cars.

On the Mercedes Benz 180, considerable attention has been devoted to preventing the transmission of road-excited noise to the body chassis structure. The front suspension, steering box and front engine mountings are all carried on a cross member, and rubber is interposed between this member and the main structure. In addition, a hydraulic damper is incorporated in the steering linkage, the springs seat on thick rubber rings, and the shock absorbers are rubber mounted. Equally comprehensive measures are taken to isolate the rear suspension, and the body panels are effectively swaged.

The noise problem in chassisless vehicles can only be solved by meticulous attention to detail in this way. Undoubtedly the principle of preventing the vibrations from reaching the structure is the correct one to adopt. Too frequently is attention devoted almost entirely to trying to damp resonant panels, that is, to the suppression of noise after it has reached, and been amplified by, the body panels and structure.

A fact that immediately becomes apparent when comparing Continental and British designs is that whereas all our own vehicles follow a more or less common pattern so far as general layout is concerned, there are wide divergences

of opinion among Continental manufacturers. The suspension systems of the vehicles already mentioned illustrate this point, so, too, does the independent rear suspension of the Renault Frégate. Engine and transmission arrangements also vary; for instance, there is the new air-cooled, horizontally opposed, twin-cylinder C.E.M.E.C. engine, the Dyna and the Citroen 2 CV air-cooled units, as well as the water-cooled, two-cylinder, two-stroke Goliath and three-cylinder, two-stroke D.K.W. units, all of which are used in conjunction with front-wheel drive arrangements.

Then there are the rear-engined cars such as the air-cooled flat-four Volkswagen, and the water-cooled, four-cylinder, in-line engine of the Renault 4 CV. Moreover, there is the torque tube and worm drive to the rear axle of the Peugeot 203. The Continental manufacturers, of course, also produce automobiles similar to the quantity-produced British cars, that is, with four- or six-cylinder in-line engines, and double transverse link front suspension systems with coil or torsion-bar springs, together with semi-elliptic rear springs and through axles.

The question that arises is whether or not British manufacturers are in a rut, or is the conventional layout best? This can best be answered in relation to each of the unconventional features in turn. Experience with all the Continental rear-engined vehicles indicates that the advantages of this layout are outweighed by its serious disadvantages, the main ones being the tendency towards oversteering and instability, and inadequate luggage space. Independent rear suspension, although it presents a number of marked advantages, is costly and British manufacturers, in our opinion, are justified in not incorporating it in their designs, at least until there is a positive demand for it.

On the subject of front-wheel drive arrangements it is unwise to be dogmatic. Provided a horizontally opposed engine layout is employed so that the bonnet is not too long, there are considerable advantages to be derived from grouping the engine and transmission together in one unit. However, despite the shortened transmission system obtained in this way, additional costs are introduced by virtue of the adoption of the flat engine layout, and by the incorporation of extra sliding and universal joints. Moreover, it is not easy to obtain an entirely satisfactory weight distribution with the front-wheel drive arrangement. Nevertheless, in very small cars, in which space is at a premium, there may well be a case for driving the front wheels and thus eliminating the propeller shaft tunnel and bulky rear axle.

There is much to be said for horizontally opposed, twin-cylinder, air-cooled engines for austerity cars. From the point of view of economy, the wet sump system must be used and cooling both of the sump and the cylinders should be effected by means of a simple fan. This arrangement calls for aluminium alloy cylinders fitted with liners, and there might be some advantage to be gained by bonding the barrels and liners together. The main problem, which is largely solved by the use of aluminium, is the dissipation of the heat from the heads down into the barrels, and thus spreading it over a large area to improve cooling. Perhaps one of the greatest disadvantages of such a layout is the noise generated. However, in an austerity car this might be acceptable.

British manufacturers of quantity-produced vehicles do not make cars smaller than 800 c.c., so it would appear that the conventional layouts that have been adopted are fully justified. It can hardly be denied that better handling and other characteristics may be obtained at a price, as is demonstrated by the performance of some of our sports and racing cars. However, the owner of a family saloon neither needs, nor is prepared to pay, for this performance.

Coachwork

There was, as usual in the Paris Show, a wide range of relatively large coachbuilt cars, but a feature that was most noticeable was a marked trend on the part of coachbuilders to turn their attention to the production of bodies for small cars. This tendency has also been present, though to a lesser degree, in Britain. In France, the Renault 4 CV chassis has been adapted to specialist bodies by a number of coachbuilders. This is of interest because it shows that, contrary to widely held views, vehicles of chassisless construction do at least in some cases lend themselves to conversion for this application. Nevertheless, the choice is restricted, and this partly explains why conversions are limited to so few models.

There are probably two reasons for the trend towards smaller coachbuilt cars. One is that the quantity-produced vehicle is, in general, much less expensive than the equivalent one-off car, and the difference between them, so far as amenities are concerned, is not sufficiently great to attract enough customers prepared to pay the higher price. The other reason is that economic conditions generally are such that fewer people are in a position to buy expensive cars; moreover, they are not prepared to face high running costs associated with large vehicles.

The policy of the manufacturers concerned has been, therefore, to offer vehicles that they can sell at a lower price and which are economical to run. The aim of the coachbuilder is to attract customers who are prepared to pay a little extra for the higher quality product and for the better performance which can be obtained from most quantity-produced engines if a little money is spent on special carburettor arrangements, manifolds, and other improvements.

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THE PARIS SHOW

Some Details of the French Exhibits

DURING the twelve months preceding this, the 40th Salon de l'Automobile, the French motor industry has settled down to what might be described as the normal conditions that inevitably have followed the exceptionally high demand for cars during the immediate post-war period. At the time of last year's Show, there were many in France who felt that a serious crisis was developing, for sales figures were then beginning to indicate a marked decline. However, it has since become obvious that this was the normal recession as the winter months approached, which had been experienced annually before the war, and which was then coming back for the first time.

There is every indication that the production figures for 1953 will be of the same order as those for 1952, that is, about 500,000 vehicles. It is of interest to compare this with the 1938 figure of 200,000 vehicles produced. The great difference between the pre-war and post-war outputs has led to speculation as to whether the home market in France is capable of supporting the industry much longer in full-scale production.

However, Baron Petiet, President of both the Comité d'Organisation du Salon and of the Chambre Syndicale des Constructeurs Automobiles, in a speech on the day before the Show opened, said that there was every reason to look forward to the future with confidence. The market, he said, was far from being saturated. Replacement needs are still considerable, for more than half the vehicles in France are of pre-war manufacture. Baron Petiet further added that the demand for motor vehicles was constantly increasing, as also was that for other amenities such as, for example, domestic and industrial electrical appliances.

In general, French manufacturers this year have tended to concentrate production on a reduced number of models. This is because competition is keen, and both low cost and reliability are factors of prime importance. These features may best be obtained by avoiding unnecessary expenditure on tooling and by retaining well-proved designs rather than by introducing changes of doubtful or slight advantage.

The export figures for the first seven months of 1953 have shown an increase of about 3·17 per cent over those for the similar period of 1952, that is, from 37,934 to 39,136 vehicles. A slight reduction in sales to French overseas territories has been compensated for by an increase in home sales.

Among the 1,300 exhibitors in the car, commercial vehicle and cycle sections were 105 manufacturers of complete motor vehicles. These included:

34 French
26 British
21 American
13 German
7 Italian
2 Czechoslovakian
1 Spanish
1 Dutch.

Eighty-five coachbuilders displayed their products. In the private car section, eleven French and three Italian manufacturers were represented. A further eleven of these eighty-five exhibited in the caravan section, and the stands of sixty different coachbuilders were to be seen in the commercial vehicle exhibition.

Quantity-produced cars

Design is of necessity influenced by the volume of production contemplated, so it is difficult to assess the relative merits of different vehicles unless some details of their respective rates of production are available. The figures given, at the end of this paragraph, for production during the first six months of 1953 are of interest in this respect. They give also some guidance as to the relative popularity of different classes of quantity-produced cars. However, it should also be borne in mind that these figures are influenced to a marked extent by the number of other models produced in the same factory and by the resources of the manufacturers concerned. In other words, sales are influenced by supply as well as by demand.

PRODUCTION FOR THE FIRST SIX MONTHS OF 1953

Vehicle	Number produced
Renault 4 CV	46,572
Peugeot 203	35,340
Simca 9	25,472
Citroen 11 B	18,126
Citroen 2 CV	16,366
Citroen 11 BL	15,265
Renault Frégate	13,392
Ford S.A.F. 12 CV	11,979
Panhard Dyna	3,324
Citroen 15 CV	1,291

That the Renault 4CV is still one of the most popular models in France is demonstrated both by the production figures and by the fact that only few changes have been considered necessary this year. An analysis of such changes is often as informative as a study of a complete description. This is because changes generally fall into two categories; the first includes entirely new features introduced to improve the vehicle, and the second is concerned mainly with modifications to improve upon the earlier version or to correct mistakes made initially. Since manufacturers with a reputation such as that of the Renault concern test their prototypes thoroughly before placing the model in full production, such mistakes as have remained undetected until the car has been placed on the market are of an obscure nature and, therefore, merit a careful study.

In the Renault 4 CV, the front seats, which are of the bucket type, have been improved by extending the backs further round each side so that they furnish better support for the shoulders. At the rear, the seat squab is more upright and thus it has been possible to push the cushion further to the rear. The amount of knee room for the rear passengers claimed to have been gained in this way is approximately 2¼ in. Provision of adequate room for the legs is important because it gives freedom for the passenger to change his position so as to avoid discomfort on long journeys. The fact that this modification has now been made after such a long production run demonstrates how difficult it is to strike a happy compromise between a comfortable squab position and adequate knee room. A change to a more vertical squab position for the rear passengers may increase head room whereas a similar change in the front seats may have the opposite effect. The reason for this seeming paradox is that the heads of the rear passengers are near to the downward-sloping part of the canopy.

No thermostat is employed in the engine coolant system; instead, a blind is fitted in front of the radiator and it may be raised or lowered to control the air flow through the block. A rapid warm-up is beneficial not only because it reduces wear in the engine, but also because the interior heating is effected by means of air drawn through the radiator. When the blind is up, so that it blanks off the radiator, little or no air passes through the interior heating system.

In the lowered position, the blind is wound on a spring-loaded roller. It is raised by a cord control, the cord being carried along the cant rail to a position above the door adjacent to the driver's seat. There the end fitting may be slipped over one of the four knobs which determine whether all, three-quarters, half or one-quarter of the radiator block is exposed. A thermometer carried in the water inlet to the radiator indicates the temperature on a dial mounted on the facia for the guidance of the driver when he adjusts the radiator blind.

One of the disadvantages of a rear-engined car is that the luggage space is inevitably restricted. This is because in

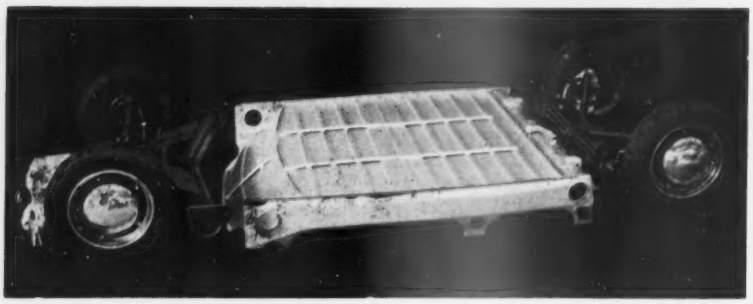
a small car the toe board of necessity intrudes into the under-bonnet space, the spare wheel is usually stowed in front, and further restriction is imposed on account of the need to provide wheelarches big enough to give clearance when the steering is in the full-lock position. In the earlier model the battery was carried low down in the space where the radiator would be in a front-engined car, and the spare-wheel was laid on the sloping dash. The 1954 model now has the spare wheel in the vertical position at the extreme front end of the under-bonnet space, and the battery is now at the rear, alongside the engine. This results in an appreciable increase in the room available for luggage, and it considerably reduces the length of the cable to the battery. However, because of its effect on the already adverse weight distribution, it is not entirely good from the theoretical point of view. Nevertheless, the manufacturers are hardly likely to have overlooked this, and are evidently satisfied that in practice the arrangement is sound.

Another modification that adds to the comfort and ease of control of the vehicle is the adoption of a lighter setting for the shock absorbers. A clutch with a sprung centre has been incorporated to reduce the tendency to judder on engagement. The heater installation has been changed, although it is still a fresh air system in which the warm air is taken from behind the engine radiator. Whereas the earlier system had long conduits under the floor to carry the warm air to outlets immediately behind the front wheel-arches, the 1954 model has a short duct to the heel board. A spring-loaded, hinged-type flap control over the orifice may be reached by the driver, or operated by the rear seat passengers.

There are two advantages to the new system. One is that the resistance to the air flow is reduced; this is more important than is generally realized. The other, again an important one, is that there is less heat loss from the short conduit to the heel board than from the two long ones used previously. Care has been taken to incorporate ducts of large section, and to avoid restrictions in the air passages and in the discharge ports.

Long ducts are used to carry the air to the de-mister slots at the bottom corners of the windscreen. For de-misting, however, humidity of the air is of equal or, in some circumstances, of more importance than its temperature. Therefore, heat losses from these pipes are not likely to cause serious loss of efficiency, for there can be little doubt that the air passing, from outside through the radiator and then into the system, would be of appreciably lower humidity than that inside the car. The manufacturers appear to have taken considerable care in the design of the de-mister jets, which are larger than usual, and which would seem to direct the air where it is of most benefit. Nevertheless, we should like to see the system in operation on a cold day before expressing a positive opinion on its efficiency.

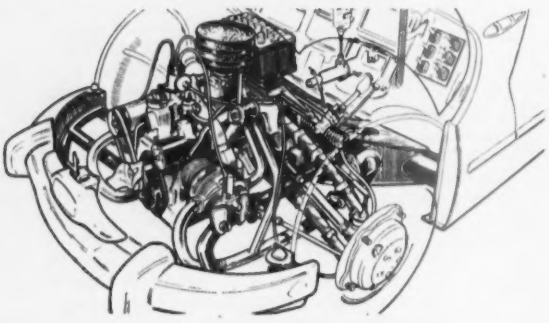
Main structure of the Dyna 54



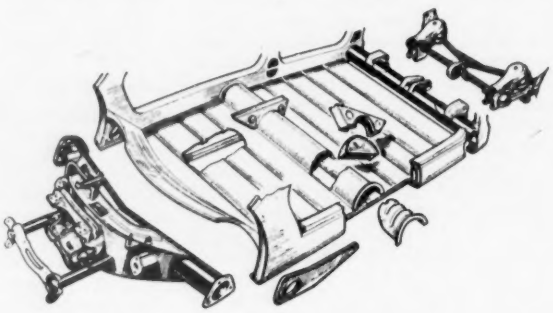
Basic components of the Dyna structure and suspension units are shown here inverted

Few modifications have been made to the Peugeot 203. The bumpers have been redesigned and extend further round the sides to give better protection to the body panels. A plain, spring-loaded trap towards the rear of the wing panel now conceals the petrol filler. Another modification that has been made is a slight change in the drip-channel arrangement over the doors. Towards the rear, the channel follows the shape of the door opening instead of conforming with the roof line. The interior lighting is switched on automatically when the door on the driver's side is opened. A larger and more curved rear window has been incorporated. The ashtrays on each side at the front are larger and an additional one has been fitted in the centre arm rest at the rear.

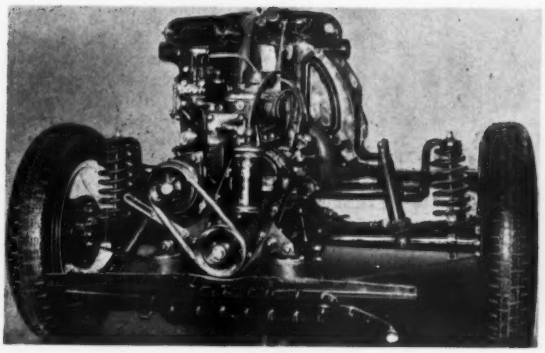
Recently, the price of the Simca Aronde has been reduced. This vehicle is of fairly recent design, so that at its present stage of development, there would have been difficulty in justifying any major changes. The radiator grille has been modified, and the bumpers have been lowered. Changes made in the electrical equipment include the incorporation of a single switch to operate all the lights; and the front winking indicators have been moved outwards, so that they are visible over



Transverse leaf springs and Houdaille shock absorbers are used on the front suspension of the Dyna 54



Exploded view of the main structural components showing how doubling plates are employed at the ends of the cross members



The new Renault 4 CV engine and rear suspension arrangement

a wider angle. Fuses have now been incorporated in the indicator circuits. The boot arrangement has been altered in that the spare wheel is now carried vertically in a transverse plane at the extreme rear, so that the luggage may be accommodated in front of it. In this way, not only has the useful volume of the boot been increased, but the spare wheel is easily accessible and may be removed without first taking out the luggage. These advantages outweigh any slight inconvenience in having to lift bags and suitcases over the spare wheel when packing them into the vehicle.

Probably the most important mechanical change is that a Gemmer worm-and-roller steering gear has been substituted for the worm-and-sector unit used in the earlier models. The only modification to the engine is that Novix or Pinet oil control rings, with expander springs behind them, are employed on the pistons. Because of the introduction of the light commercial vehicles based on this chassis, it has been necessary to strengthen the banjo type axle casing. Armstrong double-acting shock absorbers are now fitted.

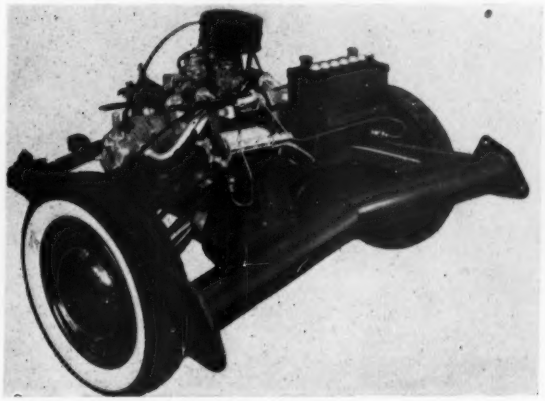
Citroen are probably unique among the large manufacturers of the world in that they have reintroduced two models which were first placed on the market seventeen years ago, but the production of which was discontinued four years later. These models are the six-light, eight-seater Familiale versions of the 11 CV and 15 CV cars. The additional seats fold forward on to the floor immediately behind those at the front. In order to accommodate these extra seats, the overall length of the 11 CV model has been increased from 15 ft 2½ in to about 15 ft 9½ in, and the wheelbase from 10 ft 1¼ in to 10 ft 9 in. The alterations to the 15 CV are as follows: the overall length has been increased from 15 ft 7¼ in to 16 ft 3 in, and the changes in wheelbase are exactly the same as in the 11 CV.

Panhard Dyna 54

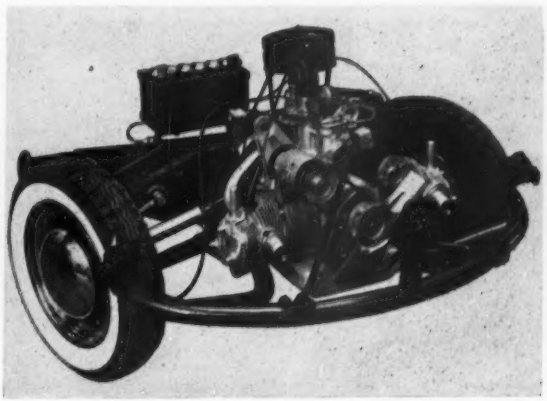
The new Dyna 54 was undoubtedly one of the most interesting exhibits among the cars produced in reasonably large quantities. From the engineering point of view, it is remarkably sound. There is much to be said for the method adopted of concentrating the load-bearing structure at the centre of the body-chassis unit, and mounting on its rear end a trailing-link suspension system, and at the front a bolted-on engine and suspension sub-assembly. That such an arrangement gives a high structural efficiency, that is, a high strength: weight ratio, cannot be disputed; for the front and rear portions of the body are not called upon to carry heavy loads and may, therefore, be of light construction.

Many manufacturers have felt dubious as to the wisdom of employing aluminium sheet for the construction of bodies manufactured in any but very small numbers. However, by introducing a new model constructed in aluminium, following their extensive experience with this material in their earlier cars, Panhard et Levassor have demonstrated that they are well satisfied with the results obtained. This model is undoubtedly an advance on the earlier design in that instead of the large aluminium castings previously employed, sheet metal is now used, almost exclusively, for the construction of the main components. We have always felt that the extensive employment of aluminium castings in private cars is economically unsound because of the thick sections, inevitable in components made in this way, in which large amounts of aluminium are extremely lightly stressed and therefore contribute little to the strength of the vehicle. Moreover, in some cases, there tends to be a larger proportion of

The Dyna 54 body has been well tested aerodynamically



View from the rear of the Dyna 54 engine and front suspension unit



On the Dyna 54, a two-bladed fan is employed to cool the cylinders

Chevrolet Sport Roadster with a plastics body

rejections from castings than from fabricated parts.

Although there is much to be said in favour of a front-wheel-drive layout in a car of any size, it has been more popular for very small cars. This is partly because of the economy involved in concentrating the engine and transmission together in a single unit, and partly because of the space saving that such a layout makes possible. In larger vehicles, employing the front-wheel-drive system, the bonnet tends to be unduly long. However, this is not the case with the Panhard, because a compact, horizontally opposed twin-cylinder, air-cooled engine is employed.

Four features have probably contributed a great deal towards making practicable the use of such a small engine. First is the high specific output, 47 b.h.p/litre, of this 850 cm³ engine which develops 40 b.h.p. Second, light alloys have been used in most of the structural work. A third contributary factor is the efficiency, already discussed, of the structural design. The fourth reason is that the body style has been specially designed to meet the aerodynamic requirements at the higher speeds of which the vehicle is capable.

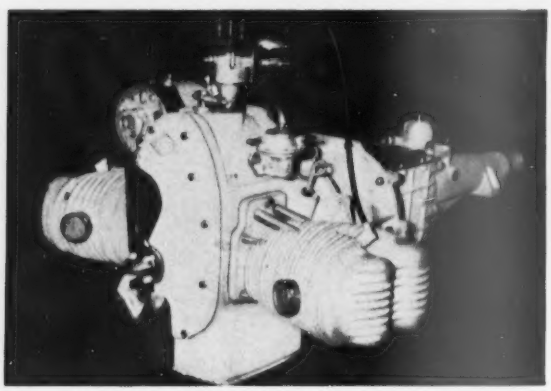
Two different methods were used in the development of the aerodynamic form of the vehicle. One involved the use of a clay model in a wind tunnel the cross sectional dimensions of which were approximately 6 ft by 7 ft. The other involved the use of air-flow indicators mounted on a car driven on the road in the normal way.

A C.E.M.E.C. engine is installed in the Rosengart Sagaie, and the plastics wings are secured by screws and washers to the steel inner panels

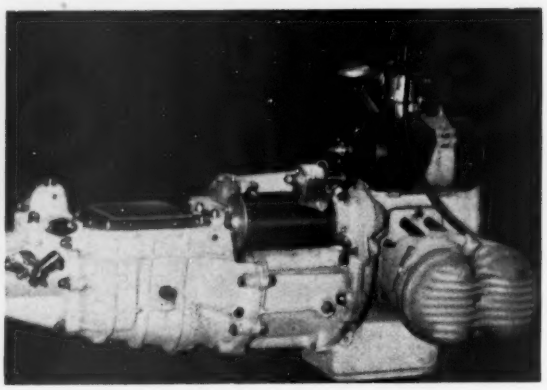
In general, there has been considerable controversy on the subject of aerodynamic shapes. This has arisen because of the difficulty of obtaining positive data on which designs may be based. Briefly, the problem is to provide a tunnel of adequate dimensions; first, to avoid interference of the air flow between the walls and the car and, secondly, to enable the vehicle to be set at an angle to the wind, so that directions of air flow resembling those experienced under all practical conditions may be obtained. An important aspect of the interference problem is that of simulating the relative motion between the ground and the car. However, this is not so difficult as the provision of a wind tunnel having a sufficiently large working section.

Panhards have approached the problem by employing a scaled-down clay model for the wind tunnel experiments. In this way, errors due to wall interference were minimized, and at the same time it was possible to set the model at various angles relative to the air flow. The effect of change of Reynolds number was, of course, taken into consideration. The air flow between the car and the ground was corrected by placing a specially designed grille on the floor in front of the car.

An advantage of using the clay model is that it is relatively easy to alter the profile as the experimental work progresses. The principal disadvantage is that it is impractical to reproduce exactly the details of the full-scale vehicle, particularly the underside. It was, therefore, necessary to supplement the wind tunnel tests with development work with the vehicle on the road. For the purpose of these tests, special air-flow indicators were designed. They each consisted of a wire, 3 in or 4 in long, to the rear end of which was attached a cone with its apex facing forwards. The front end of the wire was attached to a short pedestal mounted on a rubber suction pad, by means of which it was secured to the body. These indicators were distributed over the profile of the car in such a way as to show the direction of air flow, that is, with the wires



A one-piece crankcase and sump casting is employed in the C.E.M.E.C. engine



The dynamo of the C.E.M.E.C. unit is belt-driven from the rear of the auxiliary drive spindle

approximately parallel to that part of the body panel on which they were attached.

In order to make a record of the flow lines, it was necessary to photograph the car when it was in motion on the test track. The photographs thus obtained were projected on to a screen on which was a grid, similar to that used on the body layout boards. In this way, it was a relatively simple matter to draw in the correct shape necessary to make the body profile conform with the air flow pattern and to avoid turbulence.

The manufacturers state that the flow pattern over the Dyna 54 is reasonably free from turbulence, even when the relative wind is at an angle of as much as 30 deg from the true fore-and-aft direction. The drag coefficient is as low as 0·236. From the illustration of the car, it can be seen that the bonnet and wing shape is such as to offer as little resistance as possible to both side and fore-and-aft winds, while the vertical parts of the rear quarter panels are of relatively large area. These two features help to reduce the tendency of the centre of pressure to move forward when the relative wind changes from the true fore-and-aft direction, and improve the directional stability.

The basic structure is formed by two body sills, together with three main cross members. Additional stiffness is furnished by the door pillars, scuttle and cant rails. The floor between the sills has seven swages pressed transversely into it, to give it adequate stiffness and take up any loose metal in the panel. Two longitudinal top-hat section members are also spot-welded underneath the floor to the base of each of the swages.

The central cross member is a semi-circular pressing spot-welded on top of the floor. Before assembly, the support brackets for the seats, backed up by reinforcing brackets on the inside, are welded to the centre cross member. A flanged doubling plate, also of semi-circular form, reinforces each end of the centre cross member, which is spot-welded to the sills. This reinforcement is probably necessary because of the relatively low fatigue strength of aluminium.

A plastics body is employed on the Arista

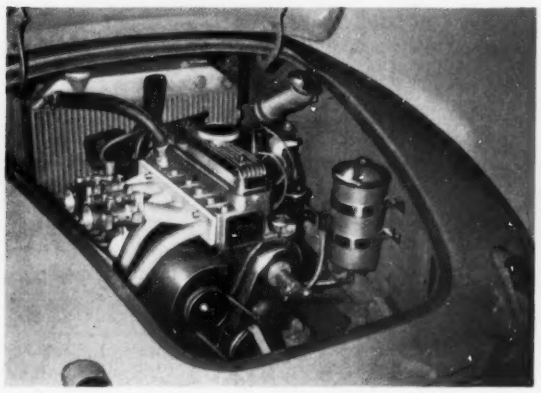
Each sill consists of the outer panel, and a main box-section member formed by two channel sections, one shallow and the other deep, spot-welded one inside the other with their flanges turned towards the centre of the car. The outer panel which, of course, is shaped to conform with the rest of the body panelling, is spot-welded to the flanges of the main box section.

All the welded and bolted junctions between transverse members and side members are made on the inner box section, thus leaving the outer panel free from blemishes. The rear cross member is made of Duralinox tube, 2·5 mm thick by about 4½ in diameter. Its ends are reinforced by sleeves, the scarfed inner ends of which extend just inboard of the welded-on lugs for the rear suspension units. This cross member is supported at each end in flanged holes in the side member to which it is welded.

The rear axle is a tubular member of wide V-shape as viewed from above. It is gusseted at the centre, where it also carries a bracket that registers between two lugs welded to the rear cross member to furnish axial location. The trailing links and torsion bars of the suspension unit, as well as the bump stops and Houdaille shock absorbers, are carried on another pair of brackets, one on each side, bolted to the lugs on the sleeved ends of the rear cross member. Each of the two spring units, which are mounted parallel to the rear cross member, consists of three torsion bars side-by-side, with their axes in a common plane. The inner ends of all three are rigidly attached to a cross piece, while the other ends of the outer pair of bars are similarly attached to the suspension bracket. The outer end of the inner bar is splined to the trailing link. Thus, torsional motion applied to the centre bar is transmitted to the cross piece which deflects accordingly and transmits the torsion to the outer pair of bars. This arrangement reduces the length necessary to accommodate the springs to such an extent that each of the two occupies less than half the width between the suspension units.

One of the greatest difficulties associated with the design of suspension units for relatively light-weight cars that are intended to carry a heavy load, in this case six persons, is the arrangement of the spring rate. The suspension should be soft enough for lightly laden conditions, but not too soft when heavily laden. Obviously, a variable rate spring is called for, and it is surprising that more manufacturers have not incorporated some such arrangement.

On the Panhard Dyna the requirements are met in an effective but creditably simple manner. The 7 in diameter bump stops are of deep



In the Antem Renault, there is a screen between the exhaust manifold and the dynamo

Engine accessibility is exceptionally good in the Autobleu Renault engine installation

section, so that they form auxiliary springs which not only increase the spring rate when the wheels deflect to the point where the two rubber stops are in contact, but also, because of their shape, themselves have a variable rate. Thus, it would appear likely that little, if any, noise would be generated when the wheels come up to the full bump position.

At the front, because of the relatively large overhang of the engine and suspension unit, and therefore, the heavy bending loads on the structure, the supporting members are of steel. The main component is a 5½ in diameter tubular cross member of a very open V-shape as viewed from above. Each end of this tube has flanges welded to it, to carry the three set bolts by means of which it is secured to the inner face of the front end of the body sill. These bolts are screwed into slugs welded to a dished doubling plate, which in turn is welded inside the sill section, to the inner plate.

By itself, this tubular cross member would not be stiff enough in torsion to carry the loads due to the overhang of the front end. Therefore, it is reinforced by a box-section member welded to its front face. The transverse leaf springs are bolted to brackets on the front face of this box-section reinforcement which also carries other brackets for the Houdaille shock absorbers and the rack-and-pinion steering mechanism. Two tubular

The new Mochet has an open duct at the front to direct air on to the cylinders of its C.E.M.E.C. engine

side members, one on each side of the engine sump, extend forward from the box section. A cross member between them carries the lower engine mounting, and two tubular extensions of these side members, bolted on at the front end, sweep forwards and outwards to join a rail that supports the bumper.

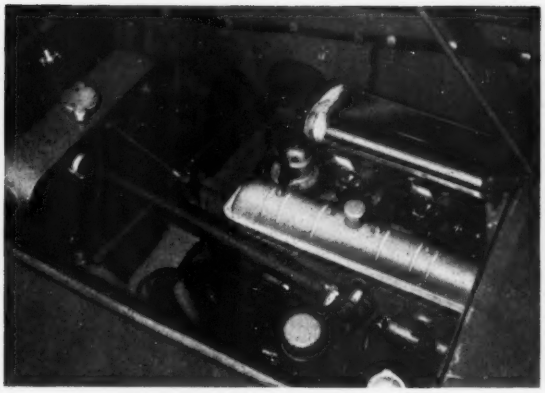
A somewhat unusual three-point engine mounting system is employed. The lower point consists of a simple rubber sandwich unit on the cross member below the engine. This unit is shaped as an arc of a circle the centre of which is on the axis of oscillation of the power unit. The upper steel member of this sandwich unit is of inverted channel section and its flanges extend downwards in front of, and behind the rubber to give fore-and-aft location. Both the other two points are rubber sandwich units bolted to brackets above the engine, one each side of the longitudinal centre line. These units are of cylindrical section with their axes fore and aft, and together with the lower one, they isolate the structure from engine torsional vibrations, and at the same time react the final drive torque which, in this front-wheel drive arrangement, is in a plane at right angles to that of the engine torsional vibrations. The remainder of the front suspension and engine layout is similar to that of the earlier Dyna models.

The general specification of the Dyna 54 is as follows:

Engine: Air-cooled, flat twin layout. Bore 85 mm, stroke 75 mm, swept volume 850 cm³. B.h.p. developed, 40 at 4,000 r.p.m. Cylinders, light alloy with integral heads. Roller bearings for main journals and big ends. Overhead valves, with torsion bar springs.
Clutch: Single dry plate.
Gearbox: Four forward speeds and reverse, with overdrive on fourth.
Final drive: To front wheels with constant-velocity universal joints on half-shafts.
Suspension: Front, independent with transverse leaf springs and hydraulic dampers. Rear, triple, transversely mounted torsion bars, with large rubber stops and hydraulic dampers.
Dimensions: Wheelbase 8 ft 5 in. Track, front and rear, 4 ft 3 in. Ground clearance, laden, 7·8 in. Overall height, laden, 4 ft 8 in. Width of front and rear seats, 4 ft 5 in. Height, rear seat to roof, 2 ft 11 in, front seat to roof, 2 ft 11¾ in. Turning circle, 31 ft.
Tyres: 145 × 400 mm, on steel rims with 5-lug attachment to spider.
Petrol tank capacity: 8·8 Imperial gal. Overall consumption claimed, 40 m.p.g.
Weight: Front end structure 83 lb. Basic central structural foundation 70 lb. Complete body with bonnet but less glass and trim, 216 lb. Total

The lead-in for the radiator air intake is extended over the doors of the Antem Renault

The Autobleu Renault was originally styled by Ghia of Turin, but is now produced under licence by Figoni



In the Nardi, the four-cylinder, 750 cm³, American Crosley engine is installed behind the front suspension unit

weight of vehicle, with full tank, spare wheel and tools, 12 cwt 86 lb.

Cars produced in smaller quantities

There were a number of plastics-bodied cars at the exhibition. Undoubtedly, the best of these was the Chevrolet Sport Roadster, of which it is intended that 5,000 shall be produced. The plastics body is 500 lb lighter than the standard metal one, the total weight of the vehicle being 2,820 lb. No information was available as to the technique employed in manufacturing the glass fibre reinforced polyester body. The specification of the vehicle is as follows:

Engine: 6 cylinders with overhead valves. Bore and stroke 90·49 mm and 100·01 mm. Swept volume 3·86 litres. Compression ratio 8:1. Output, 150 b.h.p. at 4,200 r.p.m.

Dimensions: Wheelbase 8 ft 6 in. Overall length 14 ft. Overall width 5 ft 9½ in. Sump capacity 1 gall. Petrol tank capacity, 15 gall.

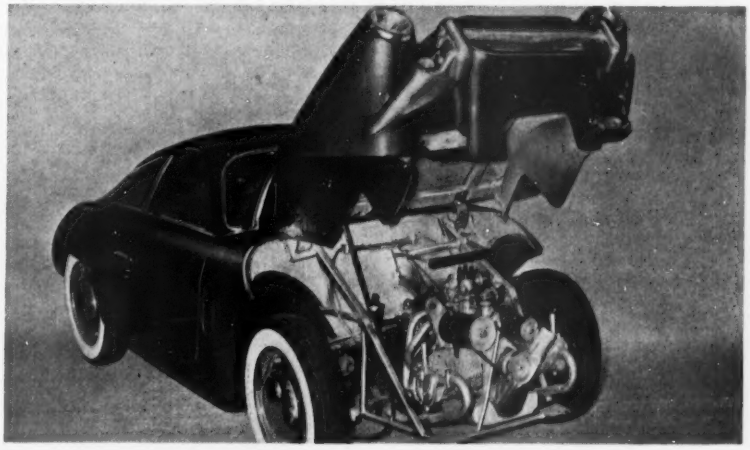
This year, Rosengart showed new models. One of these, the Sagaie saloon, is unique in that its body is made partly of plastics and partly of metal. The front wings, bonnet surround and lid are of plastics and so are the rear quarters and boot lid and door outer panel. The remainder of the vehicle, including the door inner panel and roof, are of steel. The gain in weight obtained by using composite plastics and metal construction is said to be 176-198 lb. This method of construction has two advantages. It solves a number of structural problems associated with plastics designs, since the main body components are of steel and only unstressed panels bolted on to it are of plastics. In addition, it presents an easy way out of the difficulty of moulding the roof panel and windscreen pillars in one piece with the remainder of the body.

The suspension is similar to that employed on the earlier Rosengart models, that is, with a single transverse leaf spring forming the lower transverse links at the front, with the normal semi-elliptic springs at the rear. Adjustable, friction-type shock absorbers are employed at the front, the steel plates, which are lined with friction material, are extended to form the upper transverse links of the suspension system. At the rear, telescopic hydraulic shock absorbers are employed. As in most of the French cars produced in small quantities, the steering is of the rack-and-pinion type. The principal dimensions of the vehicle are: wheelbase, 7 ft 4¼ in; track, front and rear, 3 ft 3½ in; overall length, 12 ft 9½ in; width, 4 ft 10 in; height, laden, 4 ft 7 in.

An interesting feature of this car is the engine employed. It is a C.E.M.E.C. twin-cylinder, horizontally opposed, air-cooled unit with a bore and stroke of 78 mm by 78 mm, and a compression ratio of 6·5:1. Its cubic capacity is 748 cm³, and it develops 40 b.h.p. at 5,000 r.p.m. Push rod operated, overhead valves are employed.

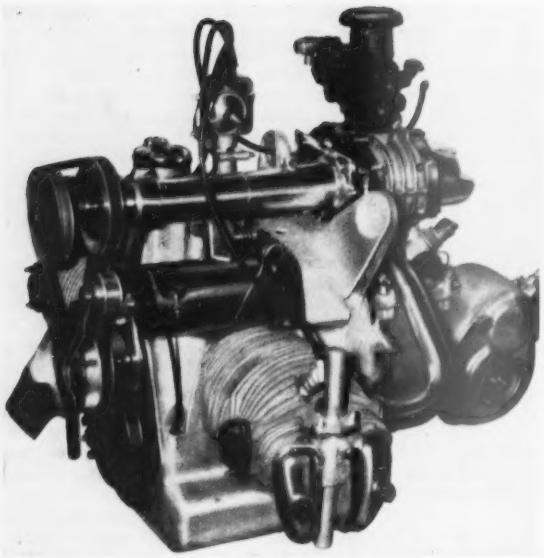
The overall width of the engine is 24 in, its depth without the distributor is 17 in and the length between the forward end of the crankshaft front extension and the rear face of the crankcase is 14 in. The flywheel has an overall diameter of 9½ in, measured over the starter ring gear, and its rim dimensions are: thickness 1⅛ in, radial width 1 in. Inside the rim, the thickness of the flywheel disc is ⅜ in. At the centre, a 4 in diameter recess is machined to form a grease trap for any lubricant that might be thrown from the clutch shaft bearing at the tail end of the crankshaft.

Although the crankcase width is 6½ in, the fan, which is mounted directly on the crankcase front extension, is only 12 in diameter. Thus, the 4 in wide fan blades extend rather less than 3 in on each side of the crankcase. It would appear that they can help but little towards cooling the cylinder heads, but their cooling effect on the oil in the crankcase and sump must be



Accessibility to the front end components could hardly be better on the Pichon et Parat Panhard

An impression of speed is given by the styling of the Pichon et Parat Panhard



The supercharged Dyna Panhard engine for the D.B. racing car

appreciable. Because of the relatively good thermal conductivity of aluminium, of which the cylinder barrel is made, the heat flow from the head down the barrel is far greater than if cast iron had been employed. It is evidently for this reason that a larger diameter fan is unnecessary. The fin spacing is approximately $\frac{1}{8}$ in, and steel liners are fitted in the barrel. The engine is mounted in such a way that the cylinders and cylinder heads are immediately behind the open ducted grille at the front of the bonnet.

It is generally considered that when an air-cooled engine is employed in a car it is necessary to incorporate a blower for cooling purposes, and that a dry-sump lubrication system should be employed. All these features involve additional expense, so that there is normally a tendency for the air-cooled unit to cost approximately the same as, or even more than, a water-cooled engine of similar power output. Moreover, air-cooled engines are generally noisy.

However, in the C.E.M.E.C. unit, most of these objections have been overcome. Moreover, it is probable that less noise is generated by the aluminium cylinders than would have been the case with cast iron components. A wet sump is cast integrally with the crankcase and has fins on its lower face. An aluminium casting bolted to the top of the crankcase carries the auxiliary drives, that is, for the oil pump and distributor and for the diaphragm-type fuel pump. The dynamo is driven by a V-belt and pulley arrangement, the driving pulley being on the rear end of the auxiliary drive spindle. The other end of this spindle is chain-driven from the front of the crankshaft and is enclosed by the cast aluminium timing cover.

Several other plastics-bodied cars were shown, but except for the fact that they were all made from glass fibre and polyester resin, no details were available. Most of them were not well finished, although in some cases this was because they were the first attempt at this form of construction, and better results are expected as more experience is gained. Among these cars were the Arista and the Reac.

Another plastics-bodied car exhibited was the outstandingly unconventional vehicle, La Symmetrique. The engine of this vehicle is mounted transversely at the front and drives a dynamo which serves four electric motors, one on each wheel. Although this arrangement eliminates the gearbox and conventional transmission components, as well as brakes, it would appear to be an expensive one. Moreover, it is difficult to see how it can ride satisfactorily with such a large unsprung mass on each wheel. Braking is effected by reversing the motors.

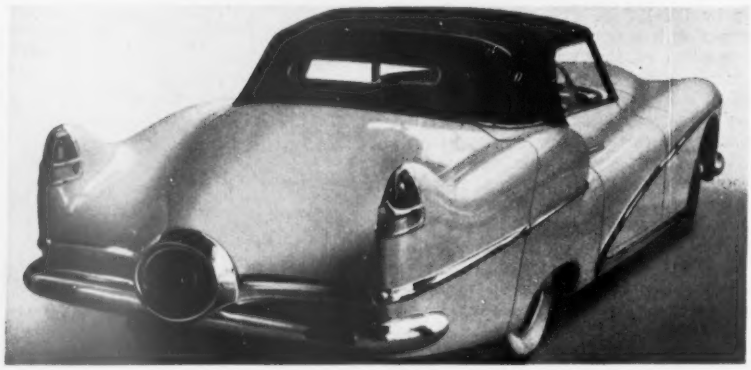
A new Mochet car, constructed from more conventional materials, was shown this year. It is a great improvement on the earlier models. The engine employed is the C.E.M.E.C. unit already described in connection with the Rosengart Sagaie. Because of its air-cooling requirements, it is mounted immediately behind a ducted grille opening. All four wheels are independently sprung. A transverse leaf spring is employed at the front in conjunction with a top wishbone link, the spring forming the lower link; at the rear, coil springs are fitted. Telescopic shock absorbers are used both at the front and the back. The whole of the front suspension unit and engine, together with the Gemmer steering gear, are mounted on a large tubular cross frame, attached to the dash structure.

A trend that was most noticeable at this year's Show was a tendency for specialist coachbuilders to concentrate on small models, notably based on the 4 CV Renault chassis. Probably the reason for this is partly the high price of petrol; but also, because of world economic conditions and intense competition from the large-scale manufacturers, they have no doubt been driven to producing vehicles at as low a price as possible. This trend is also noticeable among some of the smaller manufacturers in Great Britain.

Perhaps one of the most attractive

(*Please turn to page* 476)

The somewhat ornate T.A.I. body on a Salmson chassis



High rear wings are incorporated on the T.A.I. chassis

STATISTICAL QUALITY CONTROL

The Introduction of a Form of Sampling Inspection

L. Griffiths, M.I.Mech.E., A.M.I.E.E.

DESPITE numerous publications on the subject of Statistical Quality Control (or abbreviated, S.Q.C.) being available, it has been the Author's experience that there is a need for a concise introduction to the subject for the busy executive desirous of appreciating its purpose, operation and potentialities, and also for the company official delegated to initiate an investigation of S.Q.C.

Whilst this is the primary purpose of the present article, it will also provide the kind of information needed by the enquiring operator wishing to satisfy himself that S.Q.C. is really the aid to production it is claimed to be and not solely a means of reducing labour.

There is but one way of ascertaining the possibilities of S.Q.C. and that is to put its principles to a practical test. As will be shown, this is not difficult nor does it require more mathematical knowledge than is necessary to work out simple formulæ.

General observations

Before dealing with the operation of S.Q.C., reference will be made to some of the essential features of this method of controlling the quality of manufactured components. These notes must necessarily be brief and for a more detailed study, reference should be made to the B.S.I. Handbooks BS.600R/1942 and BS.1008/1942 and also to "Quality Control Chart Technique" by Dudding & Jennett. These the Author has found to be most helpful guides on the subject. For those desirous of still more information, the references in the appended bibliography will undoubtedly be useful.

1. *A Form of Sampling Inspection*

The method of quality control under review is a form of sampling inspection. It differs from the orthodox in that the quality of production is controlled by plotting and analyzing current data derived from each sample inspection.

2. *The Outstanding Claim*

It is the object of S.Q.C. to prevent the making of defectives during a manufacturing process as distinct from segregating defectives from a bulk quantity by an inspection at a subsequent stage.

The outstanding claim of S.Q.C. is that it affords a running commentary of quality during the manufacture of a product and thereby enables action to be taken at the first indication that the quality is going out of control. Consequently, noteworthy savings in labour and material are possible.

3. *Causes of Quality Variation*

Variation in quality is attributable to assignable and chance causes. Providing timely warning is given of assignable causes likely to impair the production quality, they can be identified and eliminated and the quality prevented from going out of control. Chance causes, not being identifiable, cannot be held in check. In general, these account for the expected quality variation as allowed for by the manufacturing tolerances.

By establishing statistical control limits—which in the first instance are computed on the assumption that the manufacturing process is just capable of meeting the drawing or specification tolerance and later are adjusted, from actual experience, to conform as closely as possible with the precision range of the machine concerned—it is possible to:

(a) Determine when, through assignable causes, the production quality is likely to go out of control.
(b) Take timely corrective action to prevent the making of defectives and so maintain the quality under control.
(c) Ensure greater uniformity of production quality.
(d) Improve the standard of quality by taking full advantage of the precision range of the machine involved.
(e) Decide reliably when a manufacturing process is incapable of maintaining the drawing or specification limits.

4. *Basis of Statistical Theory*

For any manufacturing process in which the assignable causes of variation are eliminated, the quality characteristics of the product will vary in the manner illustrated by Fig. 1. This may be taken as applicable to the case of steel bars turned to 1·000 in diameter with a tolerance of plus and minus 0·002 in but could apply equally to other products and qualities. In the specific case illustrated by Fig. 1 we have the results of measurement checks on a thousand machined bars shown in a frequency diagram form. It will be seen that nearly 60 per cent are within 0·0005 in of the nominal dimension and that roughly 90 per cent do not deviate more than 0·001 in from the nominal, although the prescribed limits allow a maximum deviation of 0·002 in.

Superimposed on the frequency diagram in Fig. 1 is a curve referred to by statisticians as the Gaussian distribution curve, which represents a typical distribution curve derived from extensive experience and a diversity of examples. This curve, which is termed the "probability curve", illustrates the results to be expected when, to quote BS.600R, "a large number of independent causes operate, by chance, to introduce deviations from an objective". When, therefore, the frequencies of quality characteristics conform to the probability curve it is reasonably certain that the variations are attributable to chance causes which cannot be eliminated. We can now see that S.Q.C. has, at least, a logical foundation and we can proceed with the application of the statistical theory to manufacturing processes.

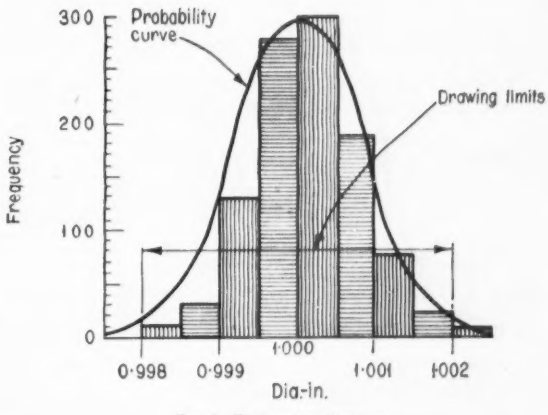


Fig. 1. Frequency diagram

5. *Application of the Statistical Theory*

One inference from Fig. 1 is that providing a manufacturing process continues to function normally and nothing unusual occurs likely to impair the production quality, subsequent batches will have the same frequency characteristics. It is, therefore, justifiable to assume that data obtained from samples taken at regular intervals during the process of manufacture would be indicative of the quality of the whole. Instead of 100 per cent inspection, a sampling inspection representing say 5 to 10 per cent of the whole would suffice for judging the production quality.

The statistical theory provides not only the means for prescribing control limits to which the quality characteristics of samples comprising a few specimens should conform, in order to ensure the specification quality of the bulk, but also provides guidance as to the size or number of each sample.

The probability curve in Fig. 1 has a definite mathematical basis, and on this basis statistical control limits for the quality characteristics of samples can be established and whenever the observed characteristics of samples fall outside these limits, an indication is given that the manufacturing process is going out of control due to an assignable cause which calls for investigation.

It will be apparent from Fig. 1 that the drawing limits cannot be the control limits for samples, since the observed values of some of the specimens in any sample will be higher or lower than the average value of the sample. Consequently, if the average value for a sample was the same as either drawing limit, some of the specimens in that sample would be outside that limit. Therefore sample control limits must necessarily lie within the drawing or specification limits. This is a point which operators find difficult to understand and often gain the impression that the tolerances have been tightened and greater skill to maintain the limits is required. This, however, is not the case and providing the control limits are appropriately set, nothing is changed insofar as the operator or the manufacturing process is concerned.

Control charts

1. *Measures of Quality*

Control charts are essential for the operation of S.Q.C. and are based on actual measurements taken on the bulk. The measures of quality normally indicated on the charts are:

Magnitude—Average values of samples of several specimens taken as manufacture proceeds.

Range—The difference between the minimum and maximum observed magnitude values in each sample.

Standard deviation—This is defined as the square root of the averages of the squares of the deviations of all the observations and its computation is exemplified later.

Two charts, average and range, or average and standard deviations, are necessary to provide complete information of the quality of the product. The average is required to maintain the correct setting and the range or deviation is essential as an index of the uniformity of the product quality. The control limits are inherently related to the average value and not to the individual measurements of the specimens and the range or deviation chart is required to show whether or not the variation of individual measurements in a sample is abnormal.

The actual statistical control limits for the average, range, and standard deviation values, to ensure that all parts produced are to the specified requirements, can be readily calculated from formulæ derived from the mathematical basis of the probability curve.

2. *Manufacturing Precision Indicated by Charts*

If the manufacturing process is incapable of maintaining the statistical control limits, it is evidence that the manufacturing precision is inadequate for the design tolerance and that either the precision of the process must be improved or the design tolerance increased to suit the process. On the other hand it may be found that the manufacturing process is easily capable of maintaining a quality characteristic closer than the specified tolerance. Advantage can, therefore, be taken of this fact to raise the general level of quality as desired, providing that in doing so the conditions imposed on the operator are not thereby made too exacting.

It will be evident, then, that one of the advantages of S.Q.C. is that it tends to maintain the highest quality level consistent with the manufacturing precision. It also affords a reliable indication as to when manufacturing plant requires overhaul, relegation to work of lower precision order, or replacement.

3. *Establishing Statistical Control Limits*

In practice it is customary to plot the average and range values on the control charts, in preference to average and standard deviation, although the latter has a certain advantage over the range value, in that it is more indicative of quality uniformity. The reason for the range values being preferred is that the computation is easier and far less lengthy and laborious than in the case of the standard deviation values. For the sake of brevity, reference will only be made to the standard deviation chart in the first example, in order to show the manner of computation. Thereafter, only the average and range charts will be considered.

The establishment of S.Q.C. limits can well be illustrated by the actual example of the author's first trial, which related to a fine limit grinding operation on a small bearing pin. The drawing limits for the ground diameters were 0·1763″H, 0·1759″L. To facilitate computations, by ensuring all positive readings, the drawing low limit was taken as the zero. The control limits were based on the data given in BS.1008/1942 and in order that the nature of the computations involved may be fully understood, the significance of the symbols employed are explained.

Nomenclature

n—Number of specimens in each sample.

m—Number of samples.

X—Quality characteristic of each specimen.

$\bar{X}$—(bar X) Average value of X for the specimens in each sample.

$\bar{\bar{X}}$—(double bar X) Grand average of all samples.

R—Range of each sample. (In BS.600R the symbol is W and this is used in preference to R in the subsequent computations.)

$\bar{R}$—(bar R) Average of a number of sample ranges. (In BS.600R the corresponding symbol is $\bar{W}$.)

σ—(Sigma) Standard deviation of each sample.

$\bar{\sigma}$—(bar Sigma) Average value of standard deviation of all samples.

The symbols A_1, A_2, D_3, and D_4, included in the average and range control chart expressions are constants for a sample size n of 4, as given in Table I of BS.1008, the values of which are 1·88, 0·729, 0, and 2·282 respectively. The constants B_3 and B_4 used for the standard deviation control limits are

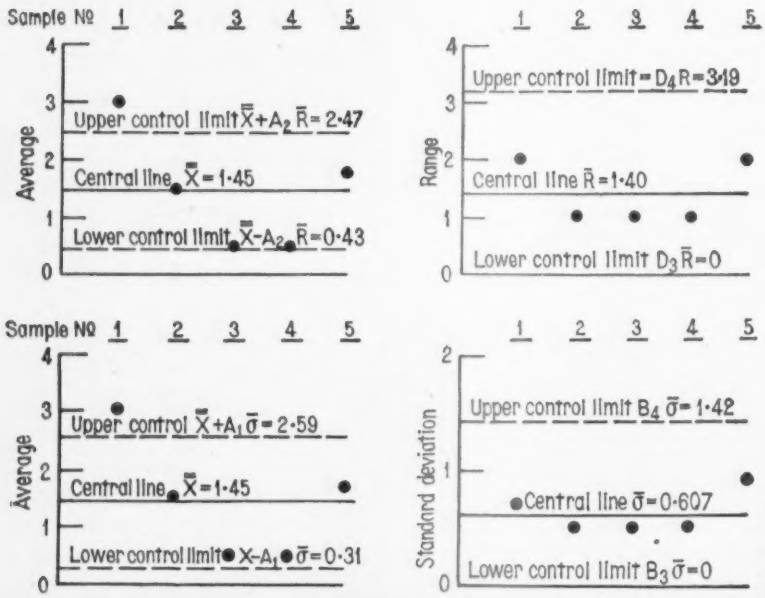


Fig. 2. Illustrating the establishment of control limits. Upper pair: "average" and "range". Lower pair: "average" and "standard deviation"

also given in the same table and their respective values are 0 and 2·33.

Briefly, the procedure was as follows:

(a) Four specimens were taken from each batch of twelve bearing pins ground, the sampling percentage being intentionally high in this first trial in order to obtain a reliable index of the production quality, upon which to base the control limits.

(b) The bearing diameter X of each specimen was measured, recorded and the average value $\bar{X}$ computed for each sample as shown below, the values of X recorded being units of 0·0001 in above the drawing low limit which, as previously stated, was taken as the zero.

m	1		2		3		4		5	
n	X	X^2	X	X^2	X	X^2	X	X^2	X	X^2
1	3	9	1	1	1	1	0	0	1	1
2	3	9	2	4	0	0	0	0	1	1
3	4	16	1	1	0	0	1	1	2	4
4	2	4	2	4	1	1	1	1	3	9
	12		6		2		2		7	
$\bar{X}$	3		1·5		0·5		0·5		1·75	

(c) The grand average $\bar{\bar{X}}$ was then computed for five samples to provide the mean of the average control limits:

$$\bar{\bar{X}}=\frac{12+6+2+2+7}{20}=\frac{29}{20}=1\cdot45.$$

(d) The range R for each sample was obtained and the average range $\bar{R}$ computed for the mean of the range control limits, thus:

$$\bar{R}=\frac{2+1+1+1+2}{5}=\frac{7}{5}=1\cdot40.$$

(e) The standard deviation value "σ" for each sample was then determined in the following manner:

Total X^2	38	10	2	2	15
Average X^2	9·50	2·50	0·50	0·50	3·750
$(\bar{X})^2$	9·00	2·25	0·25	0·25	3·062
Difference	0·50	0·25	0·25	0·25	0·688

$\sqrt{\text{Difference}}$ or σ $\quad 0\cdot706+0\cdot50+0\cdot50+0\cdot50+0\cdot828=3\cdot034$

Average σ or $\bar{\sigma}$ $\quad =0\cdot607$

(f) Upper and lower control limits for the average, range and standard deviation charts were then computed by the formulæ given against the respective limit lines in Fig. 2.

It will be seen from this example that there is nothing inherently difficult in establishing statistical control limits. The lower "average" control limit is clearly too near the drawing low limit and this indicates that some adjustment of the machine setting is necessary. This was effected for the subsequent investigations on this particular operation. This first trial, taken in conjunction with the normal 100 per cent inspection sufficed to show that S.Q.C. could be relied upon to safeguard production quality.

4. *Control Limits Compared*

In the foregoing example, the control limits were based on BS.1008. Since there is a choice of alternative limits in BS.600R, it is of interest to compare both sets of limits and this is done in Fig. 3, using the data provided by the previous example. It will be noted that there is a good measure of agreement between the BS.1008 and the BS.600R (outer) control limits for the "average" values, whilst for the "range" values, the BS.1008 limit is substantially midway between those given by BS.600R. The (inner) control limits shown in Fig. 3 are intended to be warning rather than action limits. As explained later, the practice of recording these limits on the charts was discontinued by the Author in order to save time and to simplify the charts for the operators.

The student of S.Q.C. may possibly be in some doubt in regard to the A and D constants recommended in the official handbooks. It is the Author's experience that those given in Table I of the Ministry of Supply publication "A First Guide to Quality Control", and given in Table I, can be regarded as very reliable and satisfactory. Limits computed using these constants should, however, be regarded as outer or action limits. Therefore, whenever plotted points fall on or outside these limits, corrective measures are necessary.

TABLE I. A and D CONSTANTS

Number in sample (n):	2	3	4	5	6	7	8	9	10
Constant A	1·94	1·05	0·75	0·59	0·50	0·43	0·38	0·35	0·32
Constant D	3·52	2·58	2·26	2·08	1·97	1·90	1·84	1·79	1·75

5. *Tentative Control Limits for "Average" Values*

Until sufficient process data has been obtained to compute the proper control limits, tentative limits are desirable. Such limits are obtained by adding to and subtracting from the drawing nominal size, a value equal to the drawing tolerance divided by twice the square root of the sample size, i.e., $DN \pm DT/2\sqrt{n}$. For comparison, these control limits are also shown in Fig. 3 and though displaced relative to the BS.1008 limits, they do agree reasonably well in regard to the tolerance permitted. Had the practice of using tentative limits been adopted in the foregoing example, the setting would have been more closely controlled to give an average, $\bar{X}$, nearer to the drawing nominal size.

6. *Sampling Periods*

The time interval between samplings depends on the number in the sample, the production rate and the percentage of the bulk represented by the samples. Fig. 4 has been prepared to show the sampling period in relation to the production rate per hour for a sample size of 5. From this chart it will be seen that the sampling period in minutes is roughly equal to the production time per part in seconds when, as is recommended, the samples constitute 5 to 10 per cent of the total production.

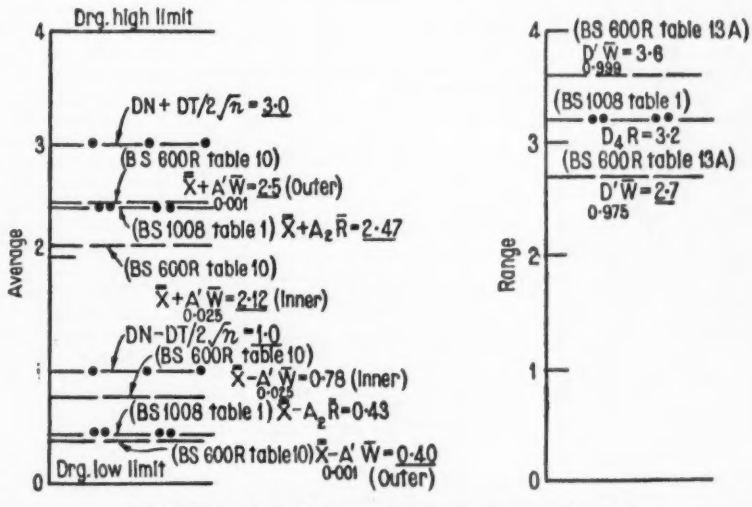


Fig. 3. Comparison of "average" and "range" control limits

Relative precision index

Mention has already been made that the control charts afforded reliable information of the manufacturing precision or variability and that it was advisable to take this into account in deciding the ultimate control limit.

In the General Electric Company's publication "Quality Control Chart Technique", this point is dealt with at some length and reference should be made to this publication for further information on the subject than can here be given.

The term "Relative Precision Index (R.P.I.)" is applied to the ratio, Total Specification Tolerance/Average Range, and when this ratio has been obtained for a particular process, the relative precision of the process can be ascertained from Table II and extracted from the publication mentioned above. If for example the R.P.I. value is computed to be 4, reference to this table will show that if the sample size was 5 or 6, the process can be classified as of High Relative Precision, since the R.P.I. value is greater than the value 3·5 given in the table.

TABLE II. RELATIVE PRECISION INDEX

Sample Size	Relative Precision		
n	Low	Medium	High
2	Less than 6	6 to 7	Greater than 7
3	" " 4	4 to 5	" " 5
4	" " 3	3 to 4	" " 4
5 and 6	" " 2·5	2·5 to 3·5	" " 3·5
State of production.	Unsatisfactory. Rejections inevitable.	Satisfactory if averages are within chart limits.	Satisfactory if averages are within chart limits.

Having decided the relative precision classification, the *average* control limits can then be suitably amended as follows:

(a) *For a Low or Medium Relative Precision Process*
Multiply $\overline{W}$ by the value of constant A (Table I) for the appropriate sample size n and then add to and subtract from the agreed objective value $\overline{X}$ which will usually be the mean of the drawing or specification limits.

(b) *For a High Relative Precision Process*
Multiply $\overline{W}$ by 0·75 for sample sizes n of 3 to 6 and add to the lower specification limit and subtract from the upper specification limit.

The above control limits for (a) and (b) are definitely action limits. If desired, inner limits can be computed and for these reference should be made to the publication mentioned.

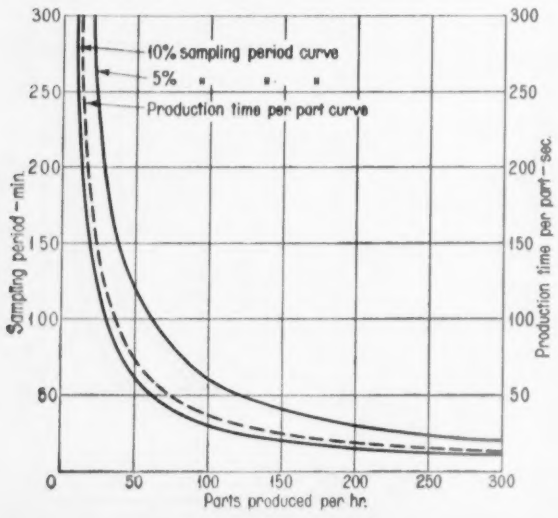


Fig. 4. Sampling periods

Experience demands simplification

Experience in the application of S.Q.C. to a battery of some forty automatic machine tools has been that strict adherence to the procedure recommended in the official handbooks entails too much clerical work and too much time taken up in establishing control limits for new jobs. This in turn occasions production delays.

1. *Simplification*

This was affected by dispensing with the computation of the inner limits, on the clear understanding that the outer limits were definitely action limits. Apart from the time saved, it was found that the operators more readily appreciated the significance of a point on or outside an action control limit.

2. *Tentative Control Limits Necessary at Outset*

To overcome the large amount of time in establishing limits on a new job, it was necessary to fix tentative "average" and "range" control limits, even without any previous knowledge of the machine concerned and before the charts were actually issued to the inspection staff. When, say, a large automatic section is operating fully on S.Q.C., requests for control charts are not infrequently received at very short notice, even though a monthly production programme is in operation. This renders it necessary for the procedure in preparing and issuing the charts to be as simple and speedy as possible.

As already explained, for the "average" chart, safe and reliable tentative limits may be computed from $DN \pm DT/2\sqrt{n}$ (see Fig. 3). These limits may be taken as the basis for computing the tentative "range" limits. For the example shown in Fig. 5, a typical steel component produced on the automatics, the tentative "range" limits were computed as indicated below. Two dimensions, a diameter and a length were controlled on this component, but for the purpose of illustration, only the diameter charts are given.

"*Average*" Control Tolerance $= DT/\sqrt{n} = 10/\sqrt{5} = 4{\cdot}48$
Control Limits $= 5 \pm 4{\cdot}48/2 = 7{\cdot}24$ and $2{\cdot}76$

"*Range*" limit derived as follows:

Assume $DT/\sqrt{n}$ tolerance = Allowable width of Control Limits

then A.W.C.L. $= DT - 2M\overline{W}$ where M is a constant given in Table III

and $DT/\sqrt{n} = DT - 2M\overline{W}$

$$\therefore \overline{W} = \frac{DT - DT/\sqrt{n}}{2M} = \frac{10 - 4{\cdot}48}{2 \times 0{\cdot}73} = 3{\cdot}8$$

Range limit $= \overline{W}D = 3{\cdot}8 \times 2{\cdot}08 = 7{\cdot}9$.

(Note—Constant D is taken from Table I.)

For the first run, several days probably, the product quality is controlled by the tentative limits. On the charts being returned, limits based on sample measurements are computed and a record made and filed for subsequent orders on the shops.

3. *Tentative Control Limits Satisfactory*

Experience on automatics sufficed to show that the tentative limits are satisfactory for medium and high relative precision processes and in the latter case tend to be slightly more exacting for the setter than necessary. This is evident from the control limits based on sample measurements and the R.P.I. as computed below:

Actual "Range" average $\overline{W}$ for 25 samples $= 2{\cdot}3$

R.P.I. $= DT/\overline{W} = 10/2{\cdot}3 = 4{\cdot}35$.

This, by reference to Table II corresponds to high relative precision.

The control limits will therefore be:

"Range" $\overline{W}D = 2{\cdot}3 \times 2{\cdot}08 = 4{\cdot}8$

"Average" (Computed as stated under "Relative Precision Index")

$\overline{W}A = 2{\cdot}3 \times 0{\cdot}75 = 1{\cdot}7$.

Upper limit $= DT - \overline{W}A = 10 - 1{\cdot}7 = 8{\cdot}3$

Lower limit $= DT + \overline{W}A = 0 + 1{\cdot}7 = 1{\cdot}7$

Widening of the average limits, as shown in Fig. 5, is therefore permissible. This, however, is accompanied by a

reduction of the range limit, since the product quality is controlled by both "average" and "range" and any change in the limits of one chart, inversely affects those of the other chart.

4. *Checking the Control Charts*

As a further check on the charts illustrated, it will be of interest to apply the procedure described in Chapter II of "A First Guide to Quality Control for Engineers". In this two conditions are laid down for a satisfactory chart, viz:

(a) The average range (W) of the first 25 samples must be less than DT×L.

(b) The "average" control limits must be within the band obtained by measuring a distance MW from each drawing tolerance.

The constants L and M are as given in Table III.

TABLE III. L and M CONSTANT

Number in sample (n):	2	3	4	5	6	7	8	9	10
Constant L	0·18	0·27	0·33	0·37	0·41	0·44	0·46	0·48	0·50
Constant M	0·80	0·77	0·75	0·73	0·72	0·71	0·70	0·69	0·69

In the case illustrated by Fig. 5, the control limits comply with these two conditions. The average range (W) being 2·3 is less than DT×L which is 3·3, whilst the control limits (8·3 and 1·7) are within the allowable limits (8·33 and 1·67) computed for condition (b).

Applying S.Q.C. to production

Many of the problems in introducing S.Q.C. are peculiar to the factory products and personnel and in these matters each factory will need to work out its own solutions.

1. *S.Q.C. Introduced for Automatic Production*

In the Author's case, a first investigation of a very tentative nature led to a consideration of the obvious, viz., a trial of S.Q.C. on automatic work. As a first step, four automatic machines were selected and for the purpose of this trial, 7·5 per cent of the production was checked for sampling. The normal 100 per cent inspection was also maintained.

During this trial, lasting several weeks, some 21,000 parts were produced and the rejection percentage for the controlled dimensions was 0·65 per cent and the rejections for all causes, including the controlled dimensions, was 1·3 per cent.

An analysis of the previous records of the same four automatics producing the same parts, revealed that the aggregate rejection percentage for a corresponding production quantity was 3·7 per cent, thereby showing a rejection reduction of the order of 3 to 1 for S.Q.C.

2. *Application of S.Q.C. Extended*

Still retaining the normal 100 per cent inspection, S.Q.C. was applied to 17 automatics. On an aggregate production of 100,000 parts and from comparative data just prior to introducing S.Q.C., a 3 to 1 reduction in rejections in consequence of S.Q.C. was again evident.

Subsequently, S.Q.C. was extended to all the automatics, though not, owing to difficulties associated with measurements, to all dimensions. Partial success in eliminating any subsequent inspection stage, was achieved by introducing the following, at the sampling periods.

(a) Gauging for small bore and other dimensions not readily measured with a micrometer or other precision instrument.

(b) Visual inspection for machining finish and incompleted operations.

The number in each sample checked visually or by gauging has, however, to be increased to 15 at least, in order to ensure a satisfactory check. Reference should be made to BS.1313/1947 "Fraction-Defective Charts for Quality Control" for information on the basis and use of fraction-defective charts where for any reason a measurement chart cannot be employed.

Experience has also shown that visual inspection for finish is necessary, particularly of threads, even when controlled for the effective diameter.

3. *Operation Procedure Adopted*

For general application experience has indicated that the chart should provide for four controlled dimensions and also give the necessary instructions for the setter and inspector. It was also considered advisable to record the measurements on the chart for each sampling period.

The operation procedure is briefly as follows:

(a) Chart sheets are prepared and issued for a monthly programme. Where previous records are available the control limits are based on sample data. Otherwise, tentative limits are given.

(b) Strictly at specified intervals, samples consisting of five parts are taken at random. The measurements are recorded and the "average" and "range" values determined. Uncontrolled dimensions are registered correct or incorrect by a "tick" or a "x".

(c) Each batch is kept separate until the "average" and "range" values are plotted. If any point is on or outside the control limits, the whole batch is gauge-checked for the dimension involved and the defectives taken out.

(d) The setter's attention is drawn to any tendency to go out of control, so that appropriate action can be taken. The setter indicates on the chart the action taken.

(e) The charts which normally last several days, are returned on completion of the work, to the issuing office for examination, so that other corrective action, such as machine overhaul or revision of limits can be taken.

Benefits of S.Q.C. summarized

The benefits of S.Q.C. confirmed and unconfirmed by the Author's experience may be briefly summarised as follows:

1. *Confirmed*

Statistical quality control does:

(a) Provide reliable quality control and can safely substitute the normal 100 per cent inspection.

(b) Reduce operational scrap to an almost negligible amount.

(c) Maintain the quality and uniformity of a product at the highest level attainable with the available manufacturing equipment.

(d) Indicate very definitely when the design tolerances are too fine for the plant and when the plant is needing overhaul, relegation to lower precision work or replacement.

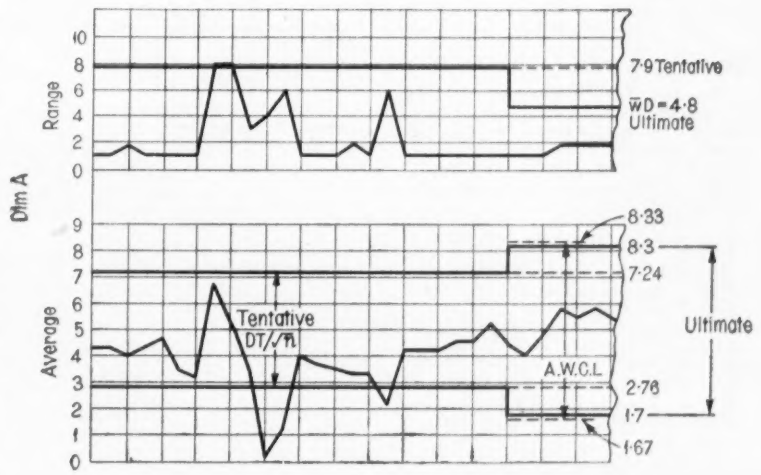


Fig. 5. Illustrating the use of tentative control limits

(e) Afford, through the control charts, a constant check on the operative personnel and enables supervisory staff to see at a glance whether or not the manufacturing process is proceeding satisfactorily.

(f) Provide reliable means of checking the performance of new equipment in relation to the maker's specification.

2. *Unconfirmed*

(a) Saves time and delay occasioned by the necessity of work passing through an inspection stage.

Practically, this is governed by the ease with which the quality characteristics can be measured. Whilst in general it was found that few components could be wholly controlled, the introduction of the gauging checks at the sampling stage increased appreciably the percentage of products that were not required to pass through an inspection cage and therefore could pass direct to the next operation or stores.

(b) Reduces Cost of Inspection.

Unless S.Q.C. is wholly applied throughout a factory, it is difficult to say what inspection cost saving, if any, is effected. Experience supports the view that S.Q.C. is not more costly to operate. The extent to which it can reduce inspection cost will depend upon the type of product, local conditions and the simplification of the control systems.

The use of a clock gauge with suitable gauging contrivance, or the adoption of some other form of high speed inspection device, will speed up the time for sampling checks.

Certainly S.Q.C. can reduce appreciably the cost of maintenance of "go" and "not go" gauges, insofar as the controlled dimensions are concerned.

Acknowledgment

The author wishes to express thanks to the British Thomson-Houston Co. Ltd., for permission to use data and knowledge acquired in the employ of that Company. He would also like to acknowledge the helpful advice given by Mr. W. W. Vinsen, Director of Manufacture, who initiated the investigation which constitutes the basis of this article.

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INSTITUTION OF MECHANICAL ENGINEERS

Forthcoming Meetings of the Automobile Division

The following meetings will be held during November:—

LONDON

Tuesday, 10th November, 5.30 p.m. General Meeting at Storey's Gate, St. James's Park, S.W.1. Paper: "Problems in the Design and Development of an Economical Automobile Gearbox," by T. C. F. Stott, M.I.Mech.E.

DERBY CENTRE

Monday, 9th November, 7.15 p.m. General Meeting in the Midland Hotel. Address by the Chairman of the Automobile Division, Professor S. J. Davies, D.Sc.(Eng.), Ph.D., Wh.Ex., M.I.Mech.E., entitled "Combustion in Compression-Ignition Oil Engines."

LUTON CENTRE

Monday, 9th November, 7.30 p.m. General Meeting in the Assembly Room, Luton Town Hall. Paper: "The Application of Power Assistance to the Steering of Wheeled Vehicles," by F. H. Heacock, A.M.I.Mech.E., and H. Jeffery, A.M.I.Mech.E.

NORTH-EASTERN CENTRE

Wednesday, 18th November, 7.30 p.m. General Meeting in the Chemistry Lecture Theatre, The University, Leeds. Paper: "Commercial Vehicle Problems, Their Investigation and Solution," by G. H. Lee, B.A., A.M.I.Mech.E.

NORTH-WESTERN CENTRE

Thursday, 12th November, 7.15 p.m. General Meeting in the Engineers' Club, Albert Square, Manchester. Paper: "The Application of Power Assistance to the Steering of Wheeled Vehicles," by F. H. Heacock, A.M.I.Mech.E., and H. Jeffery, A.M.I.Mech.E.

SCOTTISH CENTRE

Monday, 16th November, 7.30 p.m. General Meeting in the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow. Paper: "The Jaguar Engine," by W. M. Heynes, M.I.Mech.E.

WESTERN CENTRE

Thursday, 26th November, 6.45 p.m. General Meeting in the Grand Hotel, Bristol. Paper: "Commercial Vehicle Problems, Their Investigation and Solution," by G. H. Lee, B.A., A.M.I.Mech.E.

BIRMINGHAM CENTRE

Tuesday, 24th November, 6.45 p.m. General Meeting in the James Watt Memorial Hall, York House, Great Charles Street. Paper: "Problems in the Design and Development of an Economical Automobile Gearbox," by T. C. F. Stott, M.I.Mech.E.

The following meetings will be held during December:—

LONDON

Tuesday, 8th December, 5.30 p.m. General Meeting at Storey's Gate, St. James's Park, S.W.1. Paper: "Functions of Materials in Bearing Operation," by P. P. Love, B.Sc., Wh.Sc., M.I.Mech.E., P. G. Forrester, M.Sc., and A. E. Burke, B.A., G.I.Mech.E.

COVENTRY CENTRE

Tuesday, 1st December, 7.15 p.m. General Meeting in the Craven Arms Hotel, High Street. Paper: "The Manufacture and Properties of Automobile Suspension Springs," by C. J. Daswell, Ph.D., B.Sc., M.I.Mech.E., J. E. Russell, M.A., and R. Fielding.

DERBY CENTRE

Monday, 7th December, 7.15 p.m. General Meeting in the Midland Hotel. Paper: "High Speed Craft," by Commander Peter Du Cane, O.B.E., M.I.Mech.E.

NORTH-WESTERN CENTRE

Thursday, 3rd December, 7.15 p.m. General Meeting in the Grosvenor Hotel, Chester. Paper: "Functions of Materials in Bearing Operation," by P. P. Love, B.Sc., Wh.Sc., M.I.Mech.E., P. G. Forrester, M.Sc., and A. E. Burke, B.A., G.I.Mech.E

CONTINENTAL CARS

New German, Italian and Dutch Vehicles at the Paris Show

ONE of the most interesting new German cars is the Mercedes Benz 180. The four-cylinder, side-valve engine has a swept volume of 1,767 cm³. It is basically the same as that employed in the 170SV, except that the compression ratio has been altered from 6·5:1 to 6·7:1, and the power output is now 52 b.h.p. at 4,000 r.p.m.

In common with most manufacturers of cars of this type, Mercedes Benz have adopted modern flowing lines for the body, but they have retained their traditional radiator grille. However, this grille is only a light pressing attached to the bonnet, with which it lifts to give access to the engine. There is little doubt that so far as general appearance is concerned, this car represents a happy compromise between the old traditional style and the current conception of design.

In the Mercedes Benz 180, the radiator grille lifts with the bonnet

An integral body-frame structure is now used for the first time by this manufacturer. As a swing axle rear suspension has been employed, it has been possible to totally enclose the propeller shaft in a tubular tunnel which forms a backbone structure in the body floor. This has materially assisted in imparting an exceptional stiffness. Another two longitudinal members are employed, one on each side, adjacent to the body sills.

Two Y-shaped front extensions are carried forwards, more or less in a horizontal plane. The arms of the Y on each side are attached one to the sill side member and the other to the central tubular member. A cross member, also of tubular section, is welded to the ends of the legs of the Y-shaped extensions and completes the structure. Three rubber mountings, one under the centre of this cross member and one near the centre of the leg of each Y-shaped extension, support the U-shaped, box section member, fabricated from two steel pressings, on which is mounted the engine and suspension assembly. Further support for the front end is afforded by the inner panels forming the wheelarches. These panels are positively attached to the Y-members, the wings, the bonnet surround, and the scuttle sides.

An analysis of this front end arrangement shows that engine vibrations are absorbed in the first place by the engine mountings and then by the rubber units between the box section member and the main structure. A similar discontinuous path reduces the transmission of road vibrations to the structure: in this case, the shocks are absorbed first by the tyres, then by the suspension coil springs and finally by the mountings carrying the cross member. In addition, the coil springs, and also the shock absorbers, are rubber mounted, and fairly large rubber bump stops are employed. Another considerable advantage of mounting the engine and suspension sub-assembly on the cross member in this way is that the whole unit may be removed for servicing, and it also simplifies manufacture.

The recirculating-ball type steering gear has automatic backlash adjustment. A telescopic shock absorber, similar to that used in the type 300, is incorporated in the steering linkage. This, together with the fact that the steering box is on the rubber-mounted suspension and engine-support cross member, further assists in preventing the transmission of noise to the body.

The coil springs of the rear suspension are also rubber mounted, and so are the telescopic shock absorbers which, like those at the front, are co-axial with the springs. Rubber-bushed radius arms control the motion of the swing axle, which is similar to that employed on the earlier models. A single rubber mounting is interposed between the body chassis structure and the final drive casing, and the propeller shaft has a rubber-mounted intermediate bearing. Thus, it can be seen that the measures taken for the prevention of the transmission of noise from both the final drive unit and the rear suspension to the rear end structure have been as carefully thought out as those adopted at the front. In fact, it is doubtful whether any car produced in equal numbers incorporates so many details designed to reduce noise. Not only have the mechanical features already described been introduced for this purpose, but also the body panels, wherever possible, are extensively swaged.

The overall dimensions of the vehicle are: length 14 ft 7½ in, width 5 ft 8¼ in, height 5 ft 1½ in. Its kerb weight is 2,433 lb, and the dry weight is 2,358 lb. The wheelbase is 8 ft 7¼ in; track, front, 4 ft 7¼ in; and track, rear, 4 ft 9 in. A relatively large ground clearance has been adopted; with two people in the car it is 8·07 in. The turning circle is 36 ft. A four-speed synchromesh gearbox is fitted and the overall gear ratios are: top 3·89:1, third 5·95:1, second 12·76:1, first, 15·75:1, reverse 15·25:1. It is claimed that the overall fuel consumption is 32½ miles per gallon.

A happy compromise has been obtained in blending the traditional Mercedes Benz radiator form with the modern lines of the 180 model

Goliath

The Goliath car, powered by a two-stroke, two-cylinder engine, equipped with a Bosch petrol injection system is not new, but this year is the first time it has been displayed at the Paris Show. Also exhibited was the standard model equipped with a carburettor. Both are unusual in that the engine is mounted

transversely at the front. The main advantage of this arrangement would appear to be that the toe board may be brought right forward to the front suspension, thus increasing the space available for passengers. However, it must introduce some serious weight distribution problems.

The bore and stroke of the engine are 74 mm and 80 mm respectively. With the petrol injection equipment, the compression ratio is 7·7:1, and it develops 29 b.h.p. at 4,000 r.p.m., as compared with the carburettor version which has a compression ratio of 6·4:1, and develops 25·5 b.h.p., also at 4,000 r.p.m. The clutch and gearbox are in tandem in line with the crankshaft, and four forward speeds and one reverse are provided. Synchronizer units are employed for all four forward speeds. The gear ratios are: first 3·28:1, second 1·86:1, third 1·12:1, fourth 0·82:1, and reverse 3·5:1. A final drive ratio of 6·17:1 has been adopted.

A single casting forms the flywheel housing, gearbox and final drive casing. The gearbox is divided into two compartments by a central transverse web. Both the mainshaft and the layshaft are carried in three bearings, one in each end wall and one in the web. An extension of the layshaft, at the end adjacent to the flywheel, carries the final drive pinion. This pinion is straddle mounted between two bearings. One is the layshaft support bearing in the adjacent wall of the gearbox and the other is in a boss between the pinion and the flywheel. Helical spur gears, instead of the more usual bevel gears, are used for the final drive which otherwise is of a fairly conventional design.

An integral body-chassis structure is employed in the Mercedes Benz 180

In a layout such as this, the mounting of the engine and suspension unit naturally presents some problems. A cross bearer is bolted directly to the power unit at the front and is rubber-mounted on a frame cross member. The mountings used are two vertical sandwich units spaced approximately 7 in apart. The cross bearer bolted to the engine also carries the radiator, so there is no differential movement between the two. However, this is not such a marked advantage as in more conventional layouts, because in the Goliath there is no fan and therefore no danger of its fouling the radiator. A small water pump is driven in tandem with the dynamo and its function is to assist the thermo-syphon action of the coolant system. Another pair of rubber mountings is interposed between the rear of the engine and a large cross member attached to the front end of the structure. This cross member also carries the double transverse leaf spring front suspension unit.

The two cylinder, two-stroke, Goliath engine is mounted transversely in the chassis

The Moretti is one of the many small cars shown this year in Paris

Italian cars

The layout of the Lancia Appia is similar to that of the well known Aurelia, except at the rear where semi-elliptic springs are employed in conjunction with a through axle. Perhaps one of the most interesting features of this car is its engine, which is a most compact unit. Its small dimensions are mainly due to the small V-angle, only 10 deg 14 min, between each pair of its four cylinders.

The general specification of this engine is as follows: number of cylinders 4, bore and stroke 68 mm by 75 mm, swept volume 1,090 cm^3, and the compression ratio is 7·4:1. The power developed is 38 b.h.p. at 4,800 r.p.m. Its inclined, overhead valves are operated by two chain-driven camshafts actuating push rods and rockers. A diaphragm-type, mechanical fuel pump is employed, and for the lubrication system a gear-type pump is used. The water circulation is assisted by a centrifugal pump and a thermostat unit is included in the system.

A two-bearing crankshaft is fitted, and in order to obtain regular firing intervals it is, in effect, twisted 10 deg 14 min between the crank pins for Nos. 2 and 3 cylinders. The cranks for Nos. 1 and 2 cylinders are at 180 deg to one another, as also are those for Nos. 3 and 4 cylinders. The adoption of this arrangement has avoided the necessity for using two crankshafts, as in "square" cylinder layouts. In general, the unit is based on three main castings. One is the integral crankcase and sump, the base of which is closed by a shallow, dished aluminium casting. Both this casting and the sides of the sump are finned. The second main component is the cylinder block, in the base of which are studs securing it to

the crankcase. The top and bottom faces of this casting are machined horizontally. The third casting forms the cylinder head unit.

The big ends are split at 90 deg, and in the top of each small end, instead of the usual countersunk hole, there is a slot milled in a plane at right angles to the axis of the bearing. It would appear that this will collect more oil than a drilling, and is hardly likely to weaken appreciably the small end bearing boss unless the overhang on each side is too great. Because the top of the cylinder block is machined horizontally, the piston crown is at an angle of 10 deg 14 min to the axis of the skirt, that is, parallel to the joint face between the block and head. Three compression rings and two slotted oil control rings are fitted above the gudgeon pin.

Hemispherical combustion chambers are incorporated in the cast aluminium cylinder head. The sparking plugs are accommodated in deep recesses in the vee formed between the two rocker boxes. Generous water passages are provided round the valve ports, which are relatively straight and must tend to give exceptionally good breathing characteristics. An unusual feature of the valve-actuating gear is that ball ends are fitted at both ends of the tubular push rods. Those at the bottom are normal, but at the upper ends they are of relatively small section. Moreover, the ends of the tappet adjusting screws are also of small area, and they bear on hardened steel thimbles over the valve stem ends.

The three-strand timing chain is not of the normal roller type but is a development of the inverted tooth type. The links are made from hard steel plates roughly in the shape of a U, the arms of which are profiled in the manner of gear teeth. Each strand consists of two rows of these links assembled so that the leading tooth of one link is alongside the trailing tooth of the next. The centre strand is separated from those on each side by conventional side plates. All three rows of teeth on the sprockets also have a gear tooth profile to engage in the teeth of the three strands of the chain. It is claimed that this chain is more silent than the conventional roller type, but it would appear to be heavier.

In the Joymobile, the front and rear suspension units are interchangeable

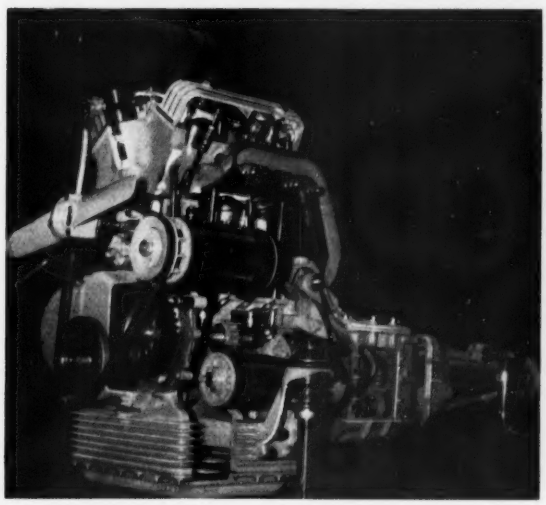
Moretti were showing two small models, a sports coupé and a four-seater saloon. The engine is a four-cylinder unit, 60 mm bore by 66 mm stroke, and with a swept volume of 748 cm³. The compression ratio is 7:1. In the saloon version, a single overhead camshaft operates the vertical valves, but in the sports model, two overhead camshafts are used in a cylinder head with inclined valves. The power developed with the two different arrangements is respectively 27 b.h.p. at 4,250 r.p.m. and 51 b.h.p. at 6,000 r.p.m.

A single dry-plate clutch is employed in conjunction with a four-speed gearbox, three ratios of which are operated through a synchromesh mechanism. The rear suspension is of conventional design with a rigid axle and semi-elliptic springs. At the front, a pair of transverse leaf springs is fitted and a worm-and-sector steering unit is employed.

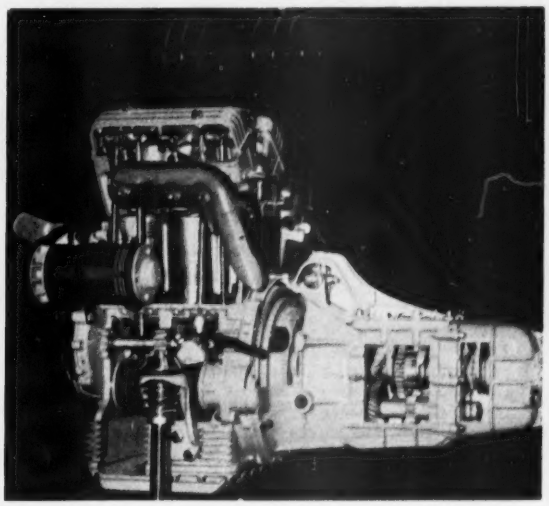
A Dutch vehicle

Washmobile Holland, of Amsterdam, displayed an unconventional vehicle called the Joymobile Turbomatic, type JTS. It is stated that construction of a series of these vehicles is to begin in 1954. Two prototypes have so far been made. The outstanding unconventional features of this car are the transmission, which is all hydraulic; the engine coolant system, in which the hydraulic transmission fluid is used and cooled in the tubular frame side members instead of in a conventional radiator; and the air-damped suspension units.

The engine is a four-cylinder, four-stroke diesel unit with a pre-combustion type head, and overhead valves.



A development of the inverted tooth timing chain is employed in the Lancia Appia engine



Coil springs and rubber are used together for the Lancia front engine mountings

It develops 45 b.h.p. at 3,600 r.p.m. and the maximum torque is 87 lb-ft at 2,400 r.p.m. The bore and stroke are 80 mm by 90 mm respectively and the swept volume is 1,780 cm^3. A compression ratio of 15:1 has been adopted, and Bosch injection equipment is fitted.

Trunnion brackets bolted on each side of the crankcase are supported in thick rubber discs in such a manner as to give the engine the appearance of being mounted on four rubber wheels on the chassis frame. A steel strip round the periphery of each rubber disc positively locates the unit. Since the transmission of power is through flexible hydraulic pipes, there is no need to restrict the fore-and-aft motion of the engine on its mountings.

Two hydraulic turbines drive the rear wheels of the Joymobile

Two large, gear-type, hydraulic pumps are driven from the tail end of the crankshaft and occupy rather less space than is normally taken by a conventional clutch and gearbox unit. The hydraulic fluid, as has already been mentioned, is used to cool the engine and it passes into the tubular frame side members at a pressure of approximately 340 lb/in^2. It then passes to the rear, whence it is carried through flexible pipes to a pair of rubber-mounted turbine units, one of which drives each rear wheel, and then back through the return circuit. Swinging half-shafts are employed between the turbines and the wheels. The rubber mountings for the turbines are similar to those used for the engine.

For reversing the vehicle and for braking, a simple control which changes the direction of flow of the fluid is employed. However, separate hydraulically operated brakes of conventional type are also fitted, and it is intended to employ disc brakes on future versions. The manufacturers claim that this transmission is simpler, quieter and easier to control than conventional mechanical systems and that the overall efficiency is from 67 to 74 per cent.

The front and rear suspension units are interchangeable. They consist of two transverse links between which is a vertical coil spring inside a large diameter pneumatic piston and cylinder unit. The lower end of each piston is attached to the stub axle forging, and at the top, the cylinder is rigidly attached to a bracket, pivot mounted on the frame. Thus, this bracket, which forms the upper link, is pivoted only at its inner end, and in this respect the system differs from a normal double transverse link arrangement. Two adjustable valves, one for the inlet and the other for the outlet, in the top of the cylinder allow air to pass in and out at a pre-determined rate. This provides the necessary damping.

Normally, a four-door, six-seater plastics body is mounted on a steel framework, on the chassis. The principal dimensions are: overall length 14 ft 7¼ in, overall width 5 ft 7¼ in, height 4 ft 10¼ in, ground clearance 7½ in, weight 1,870 lb. This chassis can also be fitted with a six-cylinder engine developing 75 b.h.p. at 2,800 r.p.m. With this power unit, the total weight is 2,150 lb. Two other versions are being considered, one with a four-cylinder and the other with a six-cylinder petrol engine. These, it is stated, will be available in sports or standard form.

DIESEL CARS

SIGNS indicate that British manufacturers are studying the possibility of marketing oil-engined private motor cars to compete with those available on the Continent. In an article entitled "Compression Ignition Engines for Private Motor Cars," in *Oil Engine*, Vol. 20, No. 238, the author states that the most suitable type of engine would appear to be a four cylinder unit of about two litres capacity. It would be required to develop 40 to 50 b.h.p. at as high a crankshaft speed as possible, in order to be able to use the transmission system in a petrol-engined version of the car. A major problem is to provide a power unit which can be controlled in exactly the same way as a petrol engine. Idling speed must be kept low, and cold starting, even with an electric heating device incorporated, may take longer than with a petrol engine. A battery of generous proportions is necessary, though it may be used for shorter periods of time than with a spark-ignition engine. Gear changing should present no difficulties; if the diesel engine gives a higher torque at low speed than the petrol engine, a conventional flywheel should be satisfactory, and three forward ratios ought to be adequate.

Due attention must be paid to the exclusion of under-bonnet air from the car interior, since the fuel system may give off unpleasant fumes. This applies especially to the air-intake of the car heating system.

Steps should also be taken to ensure the impossibility of anyone accidentally putting petrol into the fuel tank. A locked filler cap is recommended. The use of rubber engine mountings has resulted in much sweeter performance of diesel engines, and it is claimed that the diesel car need not be noisier or rougher than its petrol counterpart. If competition with Continental makes is to be successful, the additional cost should not exceed £100. *M.I.R.A. Abstract No.* 6346.

MECHANICAL HANDLING

WITH the coming season's programmes of the Institutions and official bodies, and the advent of the fourth Mechanical Handling Exhibition to be held next year, considerable interest is being shown in the film "Mechanical Handling on Show." This documentary film, which is in colour, with sound commentary, relates to some of the main exhibits at the Mechanical Handling Exhibition, which is organized biennially by *Mechanical Handling*, one of the Associated Iliffe Press publications. In addition to forming a pictorial record of this exhibition, the film also provides an excellent insight to the main types of British equipment available for the handling of goods and materials, and the commentary explains their operation and applications to industry. The film has already been shown with much success in many parts of the country, as well as abroad, and is particularly suitable for exhibition by professional and technical organizations, trade associations, engineering training colleges, Chambers of Commerce, and industrial concerns.

The film is available on loan, free of charge, upon application to *Mechanical Handling*, Dorset House, Stamford Street, S.E.1.

PLAIN BEARINGS

Some Aspects of the Design of Bearings for Automobile Engines

PLAIN bearing design and application to internal combustion engines is a highly controversial subject. So many variable factors are involved that it is difficult to formulate precise rules, but the general principles given in this article should be of assistance to designers. The variables that must be considered include the properties of the lubricant, degree of lubricant contamination, operating temperatures, type of operation, engine performance, engine structural and vibrational characteristics, and bearing materials.

One of the first decisions to be taken when bearings have to be introduced into a design is whether plain, or ball or roller types are to be used. Fortunately there is rarely any difficulty in taking such a decision since the characteristics of the two types of bearing are so different that they do not compete in the same field. Briefly, ball and roller bearings are of short length but of relatively large radial thickness; or conversely, if the radial space requirements are reduced, as in needle roller bearings, the length must be increased until they are longer than a plain bearing for the same application. The greatest advantage of these bearings is that they offer little frictional resistance to rotation. However, because of the effect of centrifugal force on the cages needed to separate the rolling elements, there is a limit to the speed at which they may be run. Splash lubrication is generally adequate for bearings of these types.

Plain bearings, on the other hand, will withstand higher loads and are more satisfactory under impact. They tend to have a longer life, and are quieter in operation. Although their radial thickness is small, they are longer than most ball or roller types. Plain bearings may be run at high speeds, if suitably designed, and are relatively inexpensive. Ample lubrication is necessary, not only to reduce friction, but also for cooling purposes. Their frictional resistance is relatively high under cold starting conditions.

Properties of materials

The next question, if plain bearings are selected, is what properties are required in materials to be used for a given application. However, before this can be settled, it is necessary to know exactly how a bearing functions. Such knowledge, together with an appreciation of the mechanical properties of the alloys available, leads to an understanding of the factors that influence the choice of materials.

It is well known that if, because of journal loading, a rotating shaft is eccentrically positioned in its bearing, the rotational motion gives rise to a hydrodynamic wedge effect, that is, a tendency to draw the lubricant between the loaded faces, Fig. 1, and to float the shaft on the oil film. This is termed full fluid lubrication, which is a state in which there is no metal-to-metal contact between the bearing and the shaft. If the speed of rotation falls or the load increases, the shaft may break through the oil film so that there is metallic contact at high points between it and the bearing. This condition is termed boundary lubrication. However, the oil molecules held in the interstices between the peaks of surface roughness and adsorbed in the outer layers of the materials still fend off the surfaces unless excessive heat is developed by friction.

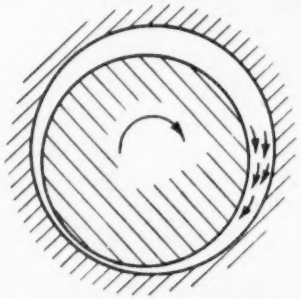


Fig. 1. Hydrodynamic wedge effect

Under conditions of full fluid lubrication, there is little to choose between the different bearing materials. However, during starting from rest, or under exceptionally heavy loads, particularly under the pulsating types of loading experienced in automobile engines, metal-to-metal contact may take place and boundary lubrication conditions obtain. In these circumstances, the materials used play an important part so far as durability and frictional characteristics are concerned. Moreover, by a suitable choice of material, the onset of boundary lubrication may be delayed.

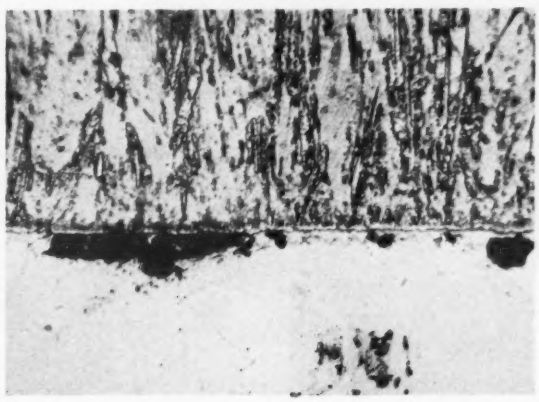


Fig. 2. A sectioned white-metal bearing showing foreign matter embedded below the surface

The two major requirements for bearings operating under boundary lubrication conditions are that friction shall be as low as possible, and that wear, corrosion and other forms of failure shall be eliminated or at least reduced to a minimum. An etched surface is highly desirable because of its oil retaining characteristics. However, chemical etching, using the lubricant as the corrosive agent, is out of the question because it would increase the rate of wear. Pre-etching would also be useless since the surface would become polished again after a very short time in use. For the same and other reasons, mechanical finishing such as honing is out of the question.

The method adopted to obtain such a surface is to employ an alloy consisting of finely divided hard particles in a softer matrix. The tendency with these alloys is for the softer material to wear faster than the harder one, and the oil is held firmly in the interstices thus formed. There are a number of other equally important reasons why materials of this type are employed, but they will become apparent as the other properties of bearing metals are discussed.

Good thermal conductivity is a desirable feature since it helps to prevent the build up of high local temperatures. These high temperatures reduce the viscosity of the oil between the rubbing surfaces and thus lower the film strength. As a result, metal-to-metal contact tends to follow, friction is increased, and failure may occur. During the war, because conventional bearing materials were in short supply, German engineers experimented with plastics bearings for crankshafts. Among the difficulties they experienced was the dissipation of the heat generated, and this problem was never satisfactorily solved.

One of the chemical properties necessary is resistance to corrosion either by oxidation products of the oil or by certain additives. Other corrosive influences to be guarded against in some types of engine include those due to combustion products of an acid nature in the blow-by

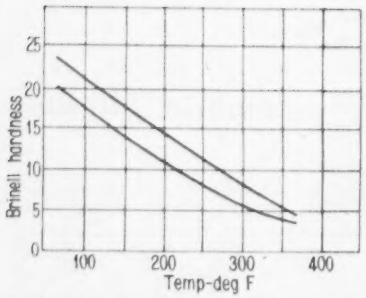


Fig. 3. Variation of hardness with temperature of lead-based bearing alloys

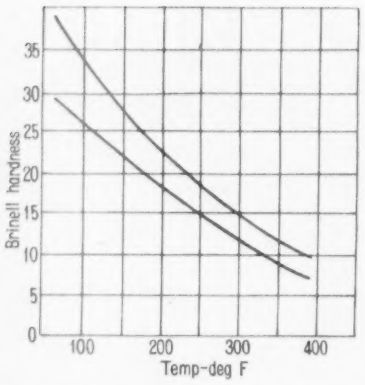


Fig. 4. Variation of hardness with temperature of cadmium-based alloys

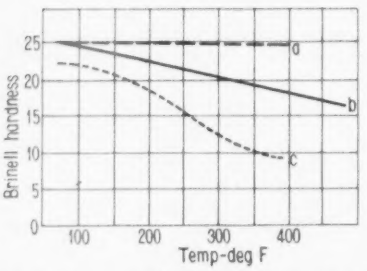


Fig. 6. Variation of hardness with temperature of

a, silver b, 70/30 copper-lead c, Satco

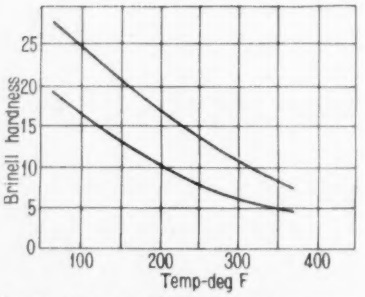


Fig. 5. Variation of hardness with temperature of tin-based alloys

gases, condensation, and sea water. The effects of corrosion are illustrated in Figs. 18, 20 and 22. When lined bearings are employed, the readiness of the materials used to bond together is an essential chemical property. Another property, about which little is known but which appears to be of considerable importance, is the ability of the bearing material to form solid metallic soaps by chemical action between the lubricant, or certain of its additives, and the metal surface. These soaps, it is suggested, act as solid lubricants. Under boundary lubrication conditions, shearing takes place in the soap films instead of in metal-to-metal welds as in dry friction. Some curves showing the frictional characteristics of different bearing materials are given in Fig. 9.

The wear process that takes place under conditions of metal-to-metal contact was described in Part I of an article entitled "Cylinder Liner Design" which appeared in the September 1953 issue of *Automobile Engineer*. Briefly, the high points on the two rubbing surfaces weld together, and subsequent shearing below the surface of one or other of the metals is the cause of wear. Therefore, it is an advantage if oxide films inhibiting the welding of the two metals are formed on the surfaces. These films tend to be more effective if the underlying metal is not so soft as to yield and thus fail to provide adequate support for them. It is essential that the hardnesses and melting points of the shaft and the bearing should differ widely: if they are equal wear can be considerable because shearing takes place in both components and the surfaces tend to become rough.

In order that the bearing may have a high load-carrying capacity, the material should have a high compressive strength at operating temperatures. Although it is desirable that the hardness should be well maintained over the range of operating temperatures, Figs. 3, 4, 5 and 6 show that this condition is not satisfied by many bearing materials. Another important feature is that adequate fatigue resistance should be well maintained up to the maximum temperature likely to be experienced. Some fatigue failures are illustrated in Figs. 15 and 19.

A low modulus of elasticity is desirable in order that elastic deformation may take place under maximum loads. This is an advantage because it allows the bearing surface to conform to the shaft when it is deflected elastically under explosion pressures or inertia loads, that is, neither permanent distortion of the bearing surface nor increases in clearance take place. A low yield strength is also desirable to permit permanent deformation during the running-in period when the shaft is bedding into the bearing, and also in order that large particles of hard foreign matter may embed level with or below the surface of the bearings, Fig. 2. In practice, the yield strength, or elastic limit, must be high enough to support the design loads without permanent deformation, but at the same time, it must be low enough to permit local permanent deformation under excessively high bearing pressures.

When shell-type bearings are used, the coefficient of expansion of the lining should be similar to that of the backing, and to the bearing housing material which is usually cast iron or aluminium. The bearing alloys should also have good casting and melting properties. That is, their composition should remain stable on remelting, they should not be subject to excessive drossing, nor should dimensional changes occur at any time subsequent to casting. It is also an advantage if the bearings can

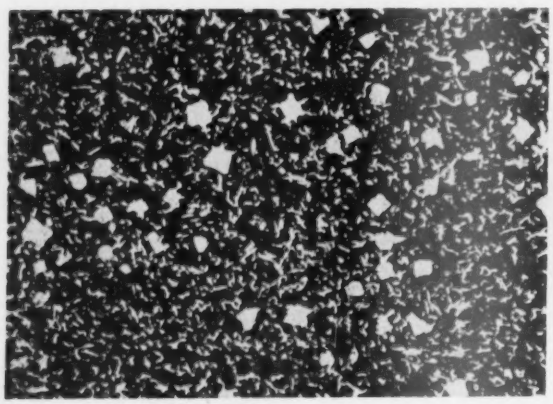


Fig. 7. A photo-micrograph of the structure of tin-based white metal

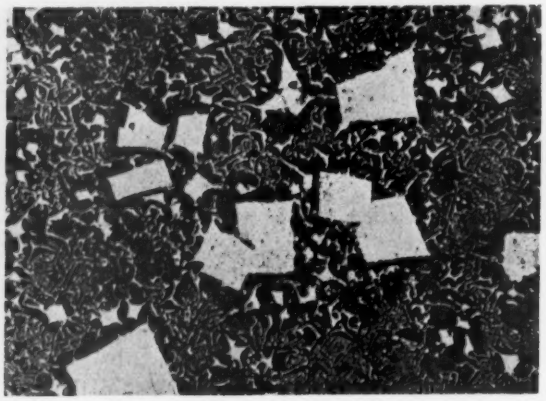


Fig. 8. A photo-micrograph of the structure of lead-based white metal

be used in conjunction with a relatively soft crankshaft. Last, but certainly not least, the bearings should be economical to produce.

Practical materials

Tin- and lead-based babbitts. The term babbitt is generally used to include alloys ranging in composition from 90 per cent or more of tin, with no lead, to 80 per cent lead and less than 5 per cent of tin. Other elements present, to make up the total of 100 per cent, include antimony and copper which are usually added as hardening elements. Cadmium, nickel, arsenic and tellurium are occasionally included. The properties of these babbitts vary with composition, but in general, all are soft enough to give good conformability and embeddability. They hold a lubricant film tenaciously and show little tendency to seizure. In addition, they are easily cast and may be bonded readily to steel or bronze. Corrosion troubles are practically non-existent, and bearings made of these materials may be used satisfactorily in conjunction with relatively soft steel shafts.

The principal disadvantage associated with these white metals is that their strength decreases rapidly with increase of temperature, so that they are liable to spread under high steady loads or to crack under fluctuating loads. However, by using bearings of large enough area to restrict the maximum pressures obtained, and by supplying them with adequate quantities of oil for cooling purposes, these alloys can be made to give satisfactory service under all but the most stringent conditions. As a general rule, it is good practice to use white metal wherever possible. Nevertheless, if space requirements limit the size of bearing that may be used, and if the loads are relatively high, such as in diesel engines, it may be necessary to use one of the stronger materials, such as the copper-lead and lead-bronze alloys. So far as cost is concerned, the price ratio of lead-bronze lined bearings to white metal lined ones is about 3:1.

Tin-based babbitts. All the high-tin babbitts in common use are based on the tin-antimony-copper system. The

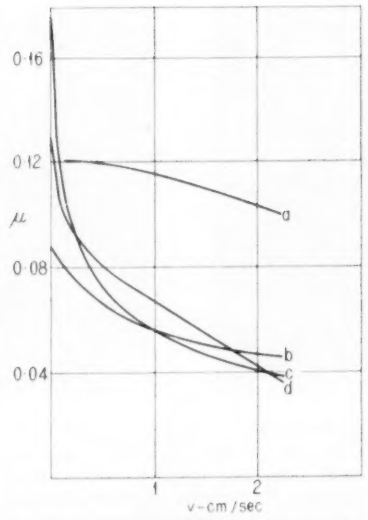


Fig. 9. Curves showing how friction varies with velocity in lubricated bearing metals; a, copper-lead b, cadmium-based alloy c, lead-based alloy d, tin-based alloy

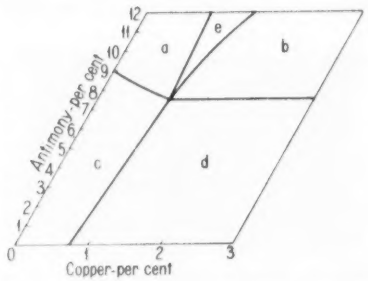


Fig. 10. Part of tin-antimony-copper system; a, matrix + SbSn b, matrix + Cu_6Sn_5 primary, and SbSn secondary c, matrix only d, matrix + Cu_6Sn_5 e, matrix + SbSn primary, and Cu_6Sn_5 secondary

structural characteristics of this system, when the tin content is high, are shown in Fig. 10. Most bearing metal alloys are represented on the extreme right-hand side of the diagram. Those in the lower area consist of a pseudo-eutectic matrix carrying dendritic Cu_6Sn_5, while alloys in the upper area have the same constituents, but cubic crystals SbSn are included, Fig. 7. As the copper or antimony content is increased, the hardness and tensile strength rise, while the ductility falls. The fatigue strength, as determined by Wohler tests or by Schenk alternating-bend tests, also increases as the percentage of antimony and copper rises. However, the resistance of these alloys to cracking in service does not seem to be directly related to the fatigue strength as determined by these methods. It would appear that at present the relative resistance to cracking of tin-based alloys can only be compared on a basis of experience. This indicates that the tendency to crack increases as the percentage of antimony and copper is decreased.

If lead is added to these alloys, a peritectic complex is formed, with a melting point of about 185 deg C, that is, about 40 deg C below that of the rest of the alloy. This, to a certain extent, reduces the strength at elevated temperatures, and the result is that wiping tends to take place under heavy loading. Lead may also give rise to minute shrinkage cavities in the alloy, a coarsening of the Cu_6Sn_5 dendritic structure, and a reduction in bond strength. Therefore, specifications for high-tin alloys usually stipulate that the lead content shall be restricted to 0·5 per cent or lower. However, it is probably only where severe conditions of loading are likely to be experienced that this restriction of lead content is necessary.

The addition of cadmium increases the hardness, tensile strength and fatigue strength of these alloys, thus reducing the tendency to failure by spreading or cracking. If the lead content is not restricted to about 0·25 per cent when cadmium is present, a ternary eutectic with a melting point of 150 deg C is formed. Nickel is sometimes added to increase resistance to cracking, but if the other constituents include cadmium, it must not be more than 0·2 per cent. Zinc, aluminium and bismuth are all detrimental.

Lead-based babbitts. These are not so expensive as tin-based alloys. Most

Fig. 11. The dendritic structure of chill-cast copper-lead

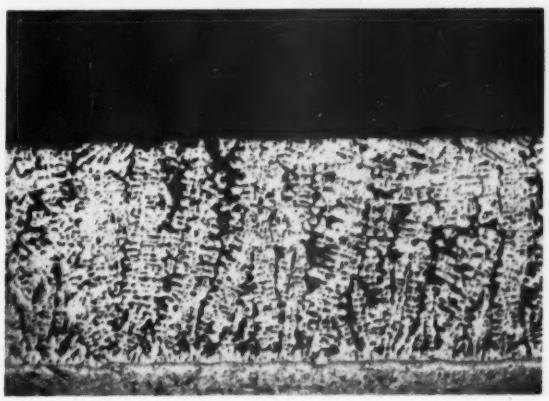


Fig. 12. Unchilled copper-lead with a dendritic structure

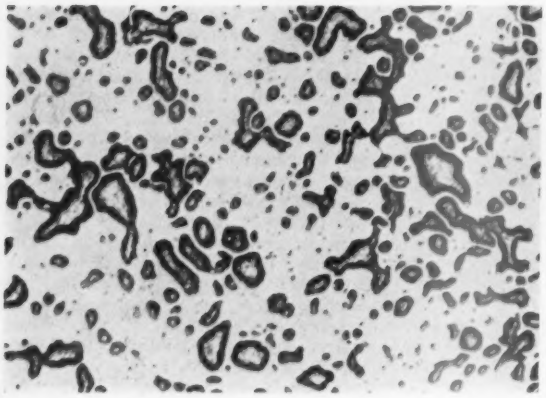


Fig. 13. Spheroidal lead grains in a copper-lead alloy

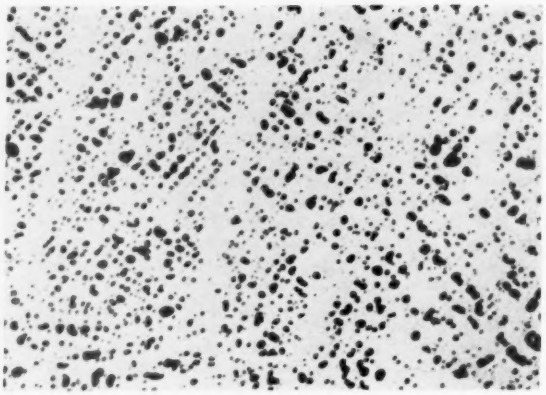


Fig. 14. Glacier LB9, 9 per cent lead-bronze

of them, as the operating temperature increases, lose hardness more rapidly, but alloys of this type have been developed which are claimed to have properties nearly as good as those of the tin-based babbitts. However, it would appear that tin-based babbitts retain a boundary lubricant film better than lead-based alloys and their thermal conductivity is higher. On the other hand, lead-based alloys are more difficult to line into bearings because of their tendency to drossing and segregation, and a satisfactory bond is rather more difficult to obtain.

Most of the lead-based alloys in commercial use are in one of two classes. The first includes those containing 12-18 per cent antimony and up to 5 per cent tin. In these alloys the primary crystals consist of an antimony-rich solid solution, and the soft matrix is mainly a ternary eutectic of phases approximating to lead, antimony and SbSn. The second class of alloys also contains about 12-15 per cent antimony but includes 10-12 per cent of tin. In these, the primary phase is SbSn in cubic form, while the matrix consists mainly of pseudo-binary eutectic of lead and SbSn, Fig. 8. This alloy generally has better properties than the first; its compressive and fatigue strengths are higher and it is more ductile. The solidus temperature of the alloys containing the ternary eutectic is 239 deg C, while those containing pseudo-binary eutectic have a solidus temperature of 246 deg C.

To restrict segregation of both the antimony-rich and the SbSn primary crystals, which are less dense than the high-lead matrix, it is usual to add copper in quantities varying between

Fig. 15. Fatigue failure of babbitt lining

0·5 and 2·0 per cent. Copper also has a slight hardening effect on these alloys and causes a marked increase in the liquidus temperature. Arsenic is sometimes added to low-tin alloys to reduce segregation and increase hardness at normal temperatures. It is also claimed to reduce the tendency towards a fall in hardness at elevated temperatures. However, arsenic seems to impair impact resistance and adhesion.

Intermediate alloys. Alloys containing 20 to 50 per cent tin have been used as bearing materials, but at elevated temperatures their properties, as indicated by mechanical tests, are inferior to both the high-tin and high-lead alloys. This is because their matrix contains the peritectic complex, which melts at about 180 deg C. However, many cases have been cited in which the substitution of a high-lead alloy for an intermediate alloy has resulted in early failure. Therefore, too much reliance should not be placed on the tests of individual mechanical properties. Experience suggests that wear resistance increases as the tin content rises. The intermediate alloys may be cast more readily than the high-lead alloys, and they are less prone to segregation. Moreover, the casting conditions are less critical so far as their effect on mechanical properties is concerned.

Copper-based alloys. When the loads likely to be experienced are too great for white metal lined bearings, it is necessary to consider stronger materials. Those most frequently used are the copper-leads and lead-bronzes. Attention should be drawn to the differentiation, which may be somewhat arbitrary, between these two classes of alloy. Copper-lead, as its name implies, is a metallurgical mixture of copper and lead; small percentages of tin or silver

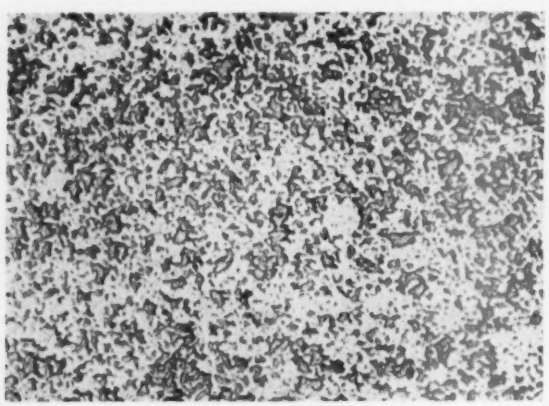


Fig. 16. Sintered 70/30 copper-lead

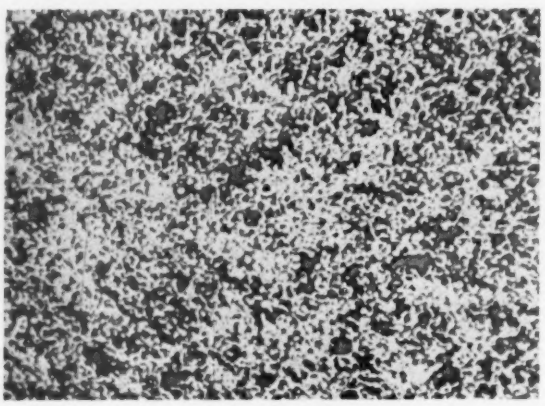


Fig. 17. Sintered 60/40 copper-lead

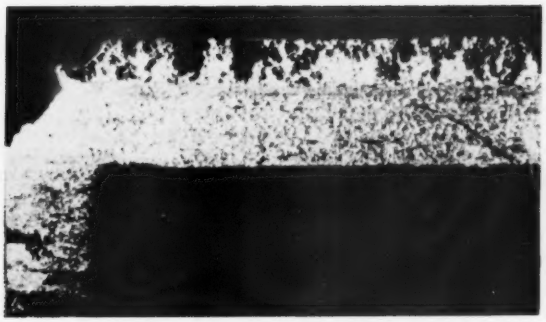


Fig. 18. Fractured section of copper-lead lined bearing following a corrosion test. The dark areas at the top are where oil has attacked the bearing metal

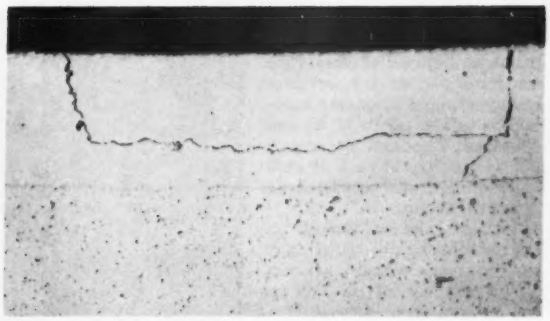


Fig. 19. A section of a babbitt bearing, magnified 22 times, showing a typical form of fatigue cracking. Eventually the centre breaks away as may be seen in Fig. 15

may be added, but the tin content does not exceed about 3 per cent. Essentially the alloy consists of a copper matrix in which are dispersed particles of lead in either dendritic, Figs. 11 and 12, or globular form, Fig. 13. The type of structure that develops depends upon the method of manufacture. On the other hand, lead-bronze is an alloy of copper, tin and lead, containing at least 4 per cent tin and sometimes a little silver. The structure consists of a bronze matrix, in which the lead is dispersed.

Copper-lead is the softest of the copper-based materials, but it is harder and stronger than the babbitts. Because of its greater hardness and inferior conformability and embeddability, it is technically desirable, and in some cases essential, that a hardened shaft is used. Care must be taken to ensure that grit and other abrasives cannot enter the lubricant, and larger running clearances must be provided. The lead particles in the alloy may be attacked by corrosive products of combustion or by acid additives that are present in some lubricants, so that an oil containing a corrosion inhibiting additive should be recommended for engines in which copper-lead bearings are employed. Corrosion may also be largely prevented by tin, lead or indium plating. In addition, the avoidance of high operating temperatures may help.

In order to increase the fatigue resistance of this alloy, tin may be added in quantities of 1 to 3 per cent. This also improves the casting properties, in that it reduces the tendency to segregation, but to some extent it reduces conformability. Since the tin enters the copper and not the lead, it does not improve corrosion resistance. Powder metallurgy may be used to increase the lead content of the alloy to more than

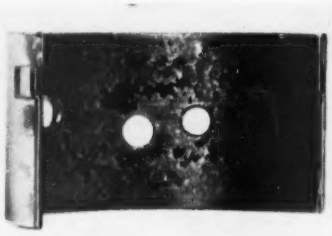


Fig. 20. A lead-bronze bearing after a severe corrosion test

40 per cent. This percentage is the limit imposed by the more conventional methods of alloying metals because the lead, when added in larger quantities, tends to segregrate.

The sintered powder alloys have a different structure from the spheroidal or dendritic types already mentioned. Opinions differ as to the relative merits of the three structures. Alloys containing spheroidal lead are often claimed to have greater fatigue resistance, but the lead in the sponge-like form of the sintered material is more continuous than in the other two, Figs. 16 and 17. This would appear to indicate that it may be easier for the lead to exude from the copper under local conditions of high loading. The same advantage may also be claimed for the dendritic structure, which is only slightly inferior in this respect. It is this property of lead, to exude and smear over the copper, which gives the alloy its good resistance to wear. The sequence of events is as follows: high local loading raises the temperature, the lead melts and, because its coefficient of expansion is greater than that of the base metal, it exudes and smears over the copper, thus reducing the coefficient of friction and therefore the temperature.

Lead-bronzes are not generally regarded as strong enough for use alone in crankshaft bearings, but must be reinforced by a backing of steel or other material. The structure of the Glacier Metal Company's LB9 specification, which is a 9 per cent lead-bronze, is illustrated in Fig. 14. One of the difficulties associated with the production of these bearings is the prevention of segregation when bonding the alloy

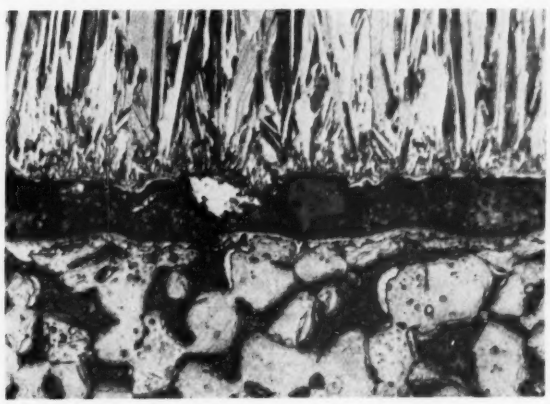


Fig. 21. This sectioned trimetal bearing shows pick-up in the overlay and some embedded foreign matter. Note : the surface was prepared for sectioning by electro-depositing copper on to it

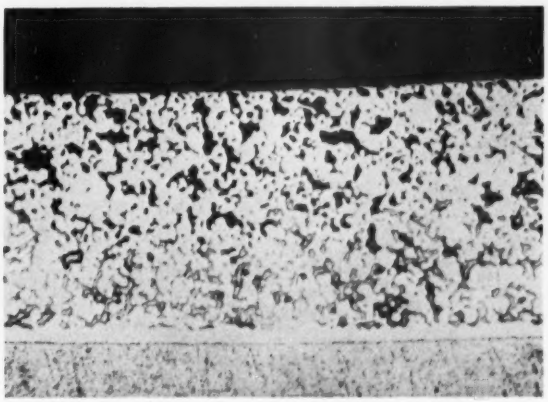


Fig. 22. The black areas of this section are where the lead-bronze grains have been corroded. Further below the surface may be seen the grey areas depicting uncorroded grains

to the backing, but powder metallurgy simplifies this problem. Alloys of this type are harder than the copper-lead ones. A typical lead-bronze alloy contains 20 per cent lead, 5 per cent tin and 75 per cent copper. Its Brinell hardness is 45 and tensile strength 11 tons/in^2.

Probably the hardest of the copper-bearing alloys are the tin-bronzes, which contain 10-15 per cent of tin and up to 1 per cent phosphorus. These are often termed phosphor-bronzes. Over this range, the cast alloys have a duplex structure, consisting of hard particles in a softer and more ductile matrix. They are, therefore, analogous to the high-tin babbitts, but their hardness is much greater. Bearings of this material are generally used for high loads and low speeds. A hard journal is required, and the alignment must be good.

Other bearing alloys. Alkali-hardened lead is one of those materials developed during the war as a substitute for high-tin alloys. One of the best known is Satco, containing 1·5 to 2 per cent tin, 0·5 to 0·75 per cent calcium, and the remainder lead with traces of aluminium, lithium, mercury and other metals. Another is Bahnmetall, the composition of which is 0·6 per cent calcium, 0·7 per cent sodium, 0·04 per cent lithium and the remainder lead. At room temperatures these alloys have properties similar to those of the high-tin babbitts but, since they have a higher melting point, they retain their hardness and strength better at elevated temperatures. The principal disadvantages of these materials are that melting and casting conditions must be carefully controlled, considerable changes may occur on remelting, and they are subject to corrosion.

The cadmium-nickel and cadmium-silver-copper alloys are rather harder and stronger than the tin- and lead-based babbitts, but they are not so good in these respects as the copper-based alloys. The Brinell hardness of cadmium-nickel at 100 deg C is about 18, as compared with 11 for a good tin-based material. There are three serious disadvantages to the cadmium-based alloys. First, they are costly; second, they are susceptible to corrosion by certain constituents and impurities in lubricating oils; and third, because of their rapid rate of oxidation in the molten condition, drossing is serious and bonding is difficult. Even indium plating, to form a cadmium-indium alloy surface layer, is not entirely successful in preventing corrosion. This is because the indium tends to combine with the nickel rather than with the cadmium and has a detrimental effect on the structure.

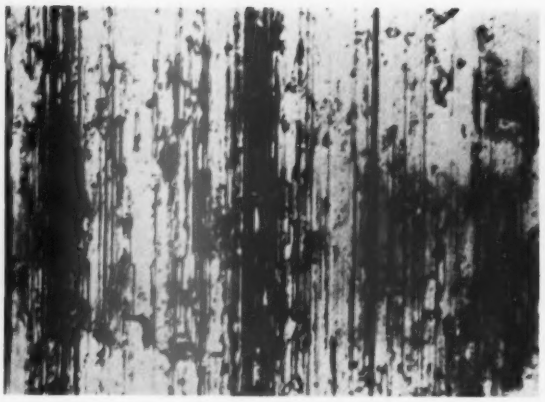


Fig. 23. A surface photograph of a lead-bronze bearing bored with a Tungsten carbide tool

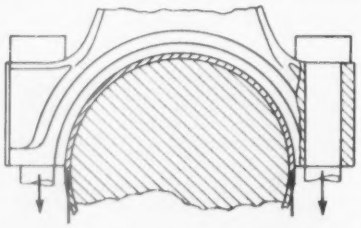


Fig. 24. Offset loads acting along the bolt axes, and the reactions at the abutting faces of the shells, tend to cause closure across the abutting faces of the cap and housing

With regard to aluminium-based alloys, two main lines of approach have been adopted. One was to develop alloys containing constituents such as iron, silicon and chromium to form a material having hard particles embedded in a relatively soft aluminium - rich matrix. The other has been to form an aluminium alloy containing a low melting point constituent, such as tin, as in the Rolls-Royce AC.9 specification.

The principal disadvantage of these materials is that they are relatively hard. For example, the Brinell hardness of RR AC.9 is about 70. It is generally considered that nitrided crankshafts, which are relatively expensive, must be used with this material. Another disadvantage is that the elastic limit of aluminium alloys is low, so that under repeated expansion and contraction due to changes in the temperature, the bearings tend to yield in compression and become loose in their housings. To overcome this, steel backed aluminium shells have been tried, but with mixed success.

Silver bearings have also been used, but they are expensive and the reports of results obtained appear to be somewhat inconsistent. Zinc alloys are prone to seizure and are suitable only for moderate loads. Cast iron bushes are sometimes used in certain applications.

This material has little embeddability or conformability, but there is a tendency for a graphite film, giving self-lubricating properties, to be formed on the bearing surface. For this reason, it is satisfactory to run a cast iron spindle in a cast iron bush.

Pre-finished, post finished, and run-in bearings

When pre-finished bearings are employed, scraping, boring and hand

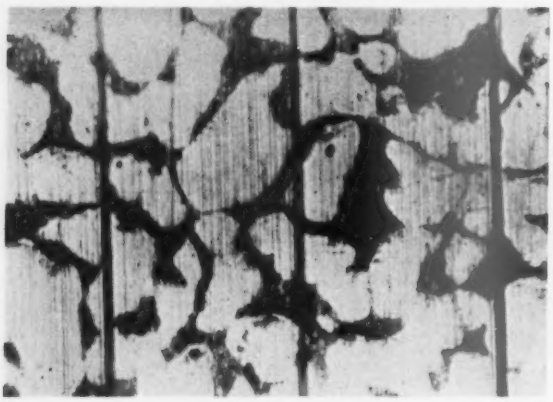


Fig. 25. The surface of a lead-bronze bearing bored with a standard diamond-tipped tool

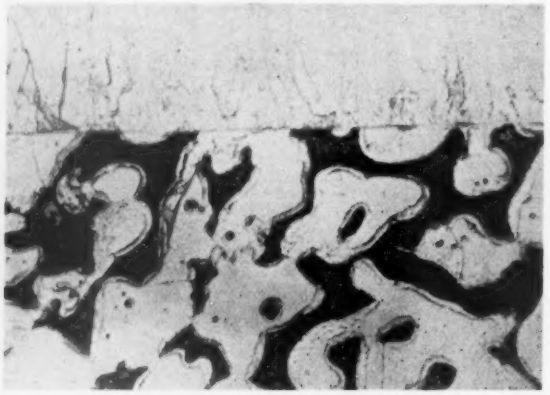


Fig. 26. A section through the bearing of Fig. 25 shows that the grains are not deformed

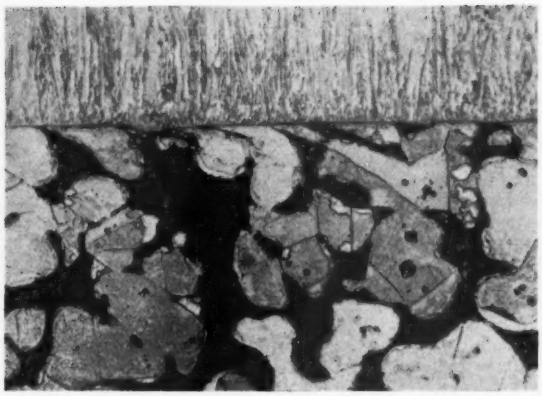


Fig. 27. This section of the bearing illustrated in Fig. 23 shows how the Tungsten carbide tool has deformed the copper grains, which have sealed off the lead

fitting are not only unnecessary but may also be positively damaging. The main advantages of this type of bearing are, of course, ease of replacement and low assembly cost. Moreover, from the point of view of replacement, the connecting-rod bearings may be renewed without removal of the piston and rod assembly, and the main bearings without removal of the crankshaft. When this procedure is adopted, care must be taken to ensure correct positioning of the locating tabs. The fitting of pre-finished bearings does not call for special equipment or for the services of highly skilled mechanics. Therefore, replacement in the field presents no great problems.

Among the disadvantages is the need for close tolerances in the housing bores and on crankpin and main journal diameters, as well as on bolt-hole and bolt diameters. In addition, running clearances will vary as between one bearing and another because of differences between the accumulations of tolerances in housings, rod bores, crankpins, journals and bearing wall thicknesses. Another disadvantage is that crankshaft misalignment due to distortion in service cannot be corrected by fitting new pre-finished bearings.

When bearings of the type that are bored or reamed in position are fitted, misalignment may be corrected during the final boring or reaming operation, and greater manufacturing tolerances are permissible. Moreover, close limits can be specified for the running clearances. This increases the effective bearing area, and reduces impact loading and noise. Such bearings, however, also have their disadvantages. Replacement is a more difficult operation requiring skilled labour. Piston and rod assemblies must be removed when replacing big-end bearings, and the engine must be taken out of the chassis to bore main bearings in line. In addition, relatively expensive boring and reaming equipment is required. This presents problems so far as field repairs under difficult conditions are concerned.

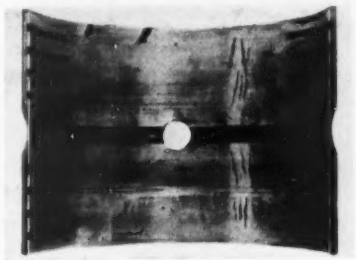


Fig. 28. The fatigue cracks of this shell are due to flexing of the cap at a point adjacent to the shoulder

In small-quantity production, bearings are sometimes directly lined into their housings. The advantages and disadvantages of this type of bearing are similar to those already given for bearings bored or reamed in position. In addition, the materials normally used for connecting rods and caps are not usually the most suitable for white metal lining. As a result, the adhesion of the white metal to its housing may be inferior unless special and expensive lining techniques are employed. A further disadvantage of this type of bearing is that it is not possible to reduce the lining thickness to an extent adequate to increase its strength.

Thick and thin-wall bearings

A thin-wall bearing is defined in the S.M.M. & T. book of standards as one in which the wall thickness is such that the geometric truth of the working surface depends on the dimensional accuracy and truth of the housing. Accuracy of machining is therefore of prime importance when these bearings are employed, and the tolerances must be specified as down from the top limit. Close tolerances must also be maintained on the wall thickness. Nevertheless, the price ratio of thick-wall:thin-wall bearing shells is about 3:1.

Few materials, even when employed in thick-wall bearings, are strong enough to be used without some form of backing. The backing must be adequate to take most of the compressive and shear loads imposed on the shell. It must also be stiff enough to prevent local flexure, which may cause fatigue failures, Fig. 28. In order that the shear loads may be transmitted effectively from the lining to the backing, a good bond between the two is essential. Another important feature, particularly in thin-wall bearings, is that when they are assembled in the housing, the nip between the halves of the shell shall be adequate to give a good interference fit between their periphery and the bore in which they are carried. If relative movement takes place between the components, fretting fatigue of the steel backing may be experienced, Fig. 33, and as the assembly becomes looser, hammering and local flexure result, and fatigue cracks tend to develop in the bearing surface.

The nip should be of such a

Fig. 29. The surface of a copper-lead bearing bored with a diamond tipped tool, with a 10 deg positive rake

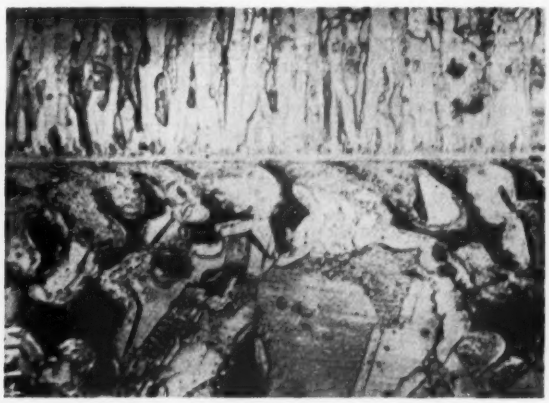


Fig. 30. A section through the bearing illustrated in Fig. 29 shows that the tool has deformed the copper

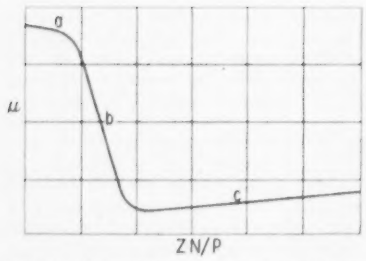


Fig. 31. Curve showing how the coefficient of friction μ varies with the dimensionless parameter ZN/P

a, boundary lubrication conditions
b, the transition stage between boundary and full flow lubrication
c, full flow lubrication conditions

magnitude that the metal of the shell is strained almost to its elastic limit. This ensures that the fit is as tight as possible without causing yielding to take place. It is advisable to make a physical check on the assembly before passing it for quantity production, rather than to rely on the calculations made at the drawing board stage. Temperature effects must be carefully considered, particularly when aluminium housings are employed. In such designs it is essential to ensure that the nip needed to give the required interference fit when the engine is hot is not so great as to cause yielding of the aluminium housing when cold. Because of the great difference between the coefficient of expansion of aluminium and that of bearing materials commonly used, it may be difficult to obtain an adequate interference fit, and generally a compromise must be made between the conflicting requirements.

When the bearing cap is assembled, the tensile loads acting through the axes of the bolts are offset from their reactions at the abutting faces of the halves of the shell, Fig. 24. This tends to cause closure across the ends of the cap, housing and shell, thus raising two high spots, diametrically opposite one another in the bore of the bearing. The consequent high local loading at these two points may cause failure. To avoid this, it is usual to machine what is known as a "joint face relief" over a length of about $\frac{1}{8}$ in-$\frac{1}{2}$ in from the abutting faces. The depth of the relief is about 0·0005 in-0·001 in at the joint face and it runs out to zero. The machining of this relief used to be a separate operation, but recently it has been effected during boring by nipping the halves in such a way that their ends close towards the bearing axis a distance of about 0·002 in on the diameter. Even when exceptionally rigid caps and housing are employed, and there is no possibility of their deflecting, the joint face relief should still be incorporated to allow for the tolerances in the location between the cap and the rod or housing.

Wherever possible, the backings, whether they are of steel or of other material, should be of plain cylindrical form. If oil transfer grooves are required, it is usually possible to machine them in the housing or cap. In directly lined bearings, dovetails keying in the linings are undesirable, for they usually result in poor adhesion arising from differential expansion; in any case, they are unnecessary if the lining technique is sound.

The question of thickness of lining to be used is important; for, as the thickness is decreased, the strength and fatigue resistance is increased. However, this improvement in mechanical properties is accompanied by a decrease in embeddability and conformability. In general, in road vehicle engines, there is little to be gained by adopting a lining thickness greater than about 0·10 in. On the other hand, when designing shell-type bearings for high specific loading, much thinner linings are to be recommended. A practical disadvantage of very thin linings is that should failure occur, the resultant knock may not be readily audible and the shaft may suffer damage before the failure is detected. They are also less tolerant of edge loading.

A satisfactory degree of embeddability may be obtained with linings of 0·005 in-0·008 in thickness, but it is

Fig. 33. Fretting and corrosion have occurred on the back of this bearing shell

generally considered that with this thickness conformability is not all that it might be. An increase in strength of 50 per cent may be obtained by reducing the thickness still further to 0·002 in. In order to avoid damage to the shaft in the event of the failure of such thin linings, backings of a bronze material of high strength have been used, with satisfactory results in some cases, but not in others.

Tri-metal bearings have been employed to overcome the disadvantages associated with the lack of conformability of shells having thin linings. In these, an overlay of softer metal is applied to copper-lead or lead-bronze linings in steel shells. Lead-indium or babbitt overlays are generally used for this purpose, and they are 0·001 in-0·002 in thick. This practice should not be confused with that of coating copper-lead or lead-bronze bearings with a lead flash, 0·00025 in-0·0005 in thick, to assist running in. The shaft may break through the flash after a relatively short mileage, and this is sometimes mistakenly regarded as a symptom of failure of the bearing. A tri-metal bearing with foreign matter embedded in the overlay is shown in Fig. 21.

Shell-type bearings are usually

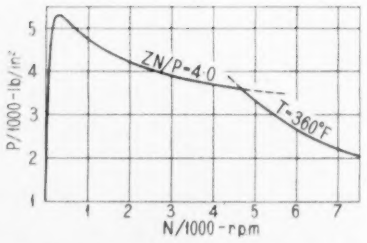


Fig. 32. Typical curve, for operation at various speeds, showing permissible bearing pressures. Above the curve is the region of unstable lubrication and below it the region of stable lubrication

located by means of a tab pressed out at one end of each half. The tabs are arranged one in front and the other to the rear of the central transverse plane of the bearing, and both register in slots milled in the abutting faces, usually on the same side, of the cap and housing. By virtue of this arrangement, it is impossible for the shells to be assembled so that the direction of rotation is such that the tabs both tend to ride out of their slots. In practice, the interference fit between the shell and the housing should be adequate for location, although the abutment between the ends of the tabs and the adjacent faces of the cap and housing helps to make the location more positive. When thick shells are employed, dowels are sometimes used for location purposes. These should be stepped, the larger diameter portion registering in the housing and the smaller one in the bearing so that there is no possibility of the dowel moving and damaging the shaft.

Surface finish and protection

In general, whenever relatively pure lead crystals are present in bearings, such as in copper-lead or lead-bronze, or if a lead overlay is employed, there is a danger of failure of the bearing by corrosion, Figs. 18, 20 and 22. This is more marked if oil temperatures are high, and with certain types of oil. Where copper-lead bearings are employed, sump temperatures should certainly be less than 150 deg C, for the rise in temperature to be expected between the time when the oil is drawn from the sump and when it is discharged from the bearing is of the order of 30 deg C.

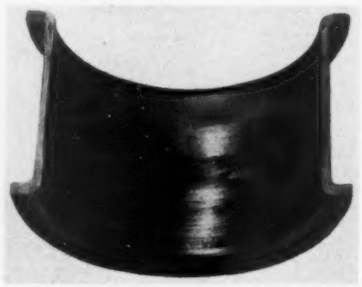


Fig. 34. Shaft deflection has caused partial failure at one end of this shell

A number of surface plating processes are employed for the prevention of corrosion. One is the already mentioned indium plating treatment of bearings made from cadmium-based alloys. On lead overlays, an indium plate of such a thickness as to form, upon subsequent diffusion heat-treatment, a lead-indium alloy containing 10 per cent indium is frequently employed. A lead-tin alloy containing about 3 per cent of tin is also corrosion resistant; it may be applied either in a manner similar to the indium coating already referred to, or by direct electrolytic co-deposition of lead and tin in the correct proportions. Steel backings are frequently tin-plated to prevent corrosion which may have the effect illustrated in Fig. 33.

Surface finish is not of great importance in babbitt bearings because of their good conformability. However, the general practice adopted by Glacier Metal Co. Ltd. is to machine all bearings with a diamond pointed tool cutting at high speed. The speeds are in the order of 2,000 r.p.m. for a 2 in diameter bore; however, in most cases they may be reduced to about 1,000 r.p.m. with satisfactory results. This method of machining gives a good appearance to the finished product, but for other reasons it is essential for copper-lead and lead-bronze bearings to be machined in this way.

In bearings made of these materials, there is a tendency, when slow speeds, or tools with dull cutting edges are employed, for the grains of copper to deform at the surface and seal off the lead, Figs. 23, 27, 29 and 30. The keen-edged diamond-tipped tools tend to cut the grains cleanly, and when high speeds are used, the inertia of the surface metal helps to prevent deformation. Figs. 25 and 26 illustrate the results obtained with diamond-tipped tools of standard form.

Journals

The first essential in the design of shafts and journals for use with plain bearings is that their stiffness and support arrangements shall be such that there is no possibility of their deflecting unduly and imposing high local loads on one or more of a row of bearings, or on one part of a single bearing. Of equal importance, of course, is that the bearing housings and surrounding structure shall be stiff enough. An example of a bearing failure due to shaft whip is shown in Fig. 34.

Journal hardness is also an important consideration. Any steel that is strong enough for crankshafts is also suitable for use with babbitt bearings. With copper-lead, 220 Brinell hardness is about the lowest that is desirable and higher figures are preferred. However, graphitic cast iron crankshafts give good service when used with copper-lead bearings, and this is probably due to the presence of graphite on the working surface and to the retention of oil in the interstices between the surface grains. With lead-bronze, nitrided or Tocco-hardened crankshafts are called for, and a figure of about 550 Brinell gives satisfactory results. In passing, it may be as well to mention that the spraying of 0·7 per cent carbon steel on to journals and crank pins, to make good any wear that may have taken place during service, is satisfactory only with white metal lined bearings. It has been applied where copper-lead shells are employed, but with mixed results.

With certain alloy iron and steel crankshafts, a feature that is frequently overlooked is that the grinding operation tends to give a minute saw-tooth finish. If the bearing runs against this, wear and seizure may result, particularly with the harder bearing materials. A micro-examination of the cross-section of a ground sample of the material used will indicate which way to grind the journal surface.

Lubrication and running clearances

In Fig. 31, a typical bearing performance curve is illustrated and it shows

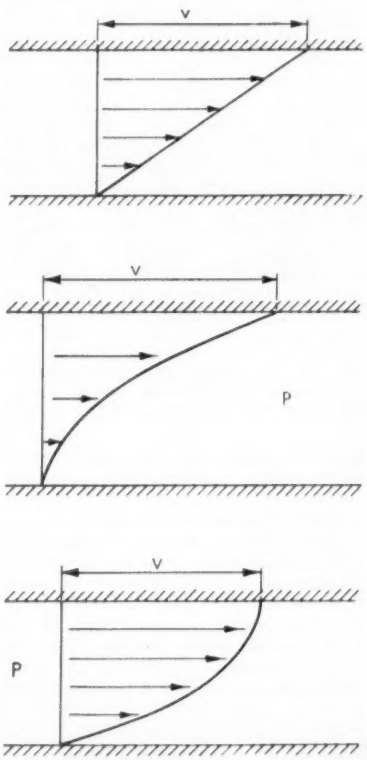


Fig. 35. Velocity distribution curves in an oil film separating two bearing surfaces

Top, with uniform pressure distribution
Centre, with the flow proceeding against a pressure gradient
Bottom, flow assisted by the pressure gradient

the coefficient of friction μ plotted against the dimensionless parameter ZN/P, or kinematic viscosity of the lubricant $\times$ the velocity of the rubbing surfaces $\div$ load. The section "c" represents the condition of full fluid lubrication while that at "b" is the intermediary stage, obtained as the change to boundary lubrication condition at "a" is approached. From this, it can be seen that if Z and P are more or less constant, a reduction in speed under full fluid lubrication conditions lowers the friction until the stage "b" is reached. The shaft cannot run for long under this intermediary condition because friction increases sharply as velocity is reduced. This not only in itself tends further to reduce the engine speed, but it also increases the rate of generation of heat. Under these conditions the viscosity becomes less, further lowering the value of the parameter ZN/P so that there is a tendency to change to the boundary lubrication conditions at "a."

The aim, therefore, is to design bearings to operate under conditions remote from the point where unstable lubrication begins. Nevertheless, during starting and stopping, the change from full fluid to boundary lubrication inevitably occurs. Since the viscosity of the lubricant varies with temperature, the balance between heat generation and dissipation must be taken into account when deciding the permissible operating conditions of a bearing.

For this reason, pressure/velocity curves for materials are of little help in the design of bearings for internal combustion engines. A typical curve, obtained from experimental results showing how permissible pressures vary with speed, for a constant value of ZN/P = 4·0, is given in Fig. 32. The area above the curve represents conditions of unstable lubrication while below it, the lubrication conditions are stable. From the illustration, it can be seen that as the r.p.m. increases from zero, the permissible load increases rapidly until conditions of full fluid friction are obtained. It then falls off relatively slowly because of the higher temperatures developed as the engine speed increases, until finally it is the stability and other properties of the oil, and not the strength of the bearing material, which impose the limit.

Under the sparsely lubricated conditions obtained for a very short period immediately on starting up, the shaft normally runs partly on films of oil held in the interstices and partly on metallic soaps, formed on the surface of the bearing metal and/or on the journal. These metallic soaps have been mentioned earlier in this article, but at this stage it is necessary to give further details concerning them.

Modern lubricating oils contain a number of different classes of additives. One of these is the fatty acids, and another is the E.P. additive range which may include chlorides, phosphides and sulphides. These additives attack the surfaces of the bearing and journal and leave on them films of chemically attached molecules, which are the soaps referred to. The pressures required to penetrate these films can be very high, and since the soaps have a relatively low shear strength, shearing takes place in the soap films rather than in the metal, and the resistance to motion is low.

If surface contact does occur,

Fig. 36. Curves showing oil film pressure distribution over the length of a plain and grooved bearing

chemically active bare patches of metal are exposed. These are immediately attacked by the E.P. additives which, because their radicals have a greater affinity for the exposed material, form metal salts. For a very short period the salts prevent further metal-to-metal contact, but they are subsequently acted upon by the fatty acids which re-form the soap film.

As the engine continues to gain speed after starting, and the full flow of oil begins to pass through the bearings, the final stage in the lubrication process is established. Under these conditions, hydrodynamic wedges are formed and full fluid lubrication develops. However, when running at full load, boundary lubrication may again occur during parts of the cycle notably when the gas pressure loads are at their peak.

One of the main essentials, so far as oil supply is concerned, is the avoidance both of cavitation of the oil, and the drawing of air into the bearing. It is, therefore, necessary to understand the laws governing the flow of oil between the two surfaces. Under conditions of constant pressure, when there is relative motion between two surfaces separated by a film of oil, the flow diagram showing the velocity distribution in the oil film is a straight line, as in Fig. 35 (top). If, on the other hand, there is an increase of pressure, that is, the flow takes place against a pressure gradient, as might happen as a result of a hydrodynamic wedge effect, there is a tendency for the diagram to take a convex form, as in Fig. 35 (centre), and if the pressure decreases, the curve is of concave shape, Fig. 35 (bottom).

However, when calculating the head of oil, or spouting pressure, necessary to ensure that the bearing is adequately supplied, it is usual to assume that the straight line diagram applies, Fig. 38. Thus, the mean oil velocity is half the rubbing velocity of the journal relative to the bearing. In fact, the formula used to estimate the head required is $v = \sqrt{2gh}$, where v is the mean velocity of flow in feet per second, g is 32, and h is the head of oil in feet. This head is usually small by comparison with that required to overcome the viscous friction in the oil feed passages. In big-ends, centrifugal force tends to increase the pressure head of the oil. So far as possible, the oil hole in the journal should break through the surface at a point well away from the area of maximum prolonged load and it should be in the diverging part of the clearance formed when the shaft is running eccentrically under load. If it is located in the converging portion, it may reduce the effectiveness of the hydrodynamic wedge and there may be a tendency for the oil to be pumped out of the bearing through the hole.

The Cleveland Graphite-Bronze Co. have recommended, in a book entitled "Sleeve Bearing Materials," published in 1949 by the American Society for Metals, that the flow through crankshaft bearings should be 30 gallons per minute, per square inch of leakage area. The clearance adopted depends on the bearing diameter and material. In general, larger clearances are required with copper-based alloys because of their relatively poor embeddability and conformability as compared with the babbitt materials. This is not only to leave a greater space between the surfaces for the passage of foreign matter, and to allow for shaft deflections, but also because more frictional

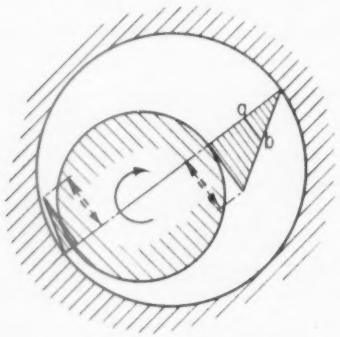


Fig. 38. A straight line distribution is assumed when estimating spouting pressures, and ab represents the mean velocity

heat is generated by copper-based alloys under boundary lubrication conditions, so a larger quantity of oil must be passed through to carry away this heat.

The following running clearances for thin-wall bearings have been recommended by the Big Six Standardization Committee. In white-metal main bearings, the clearance should be 0·001 in for shafts of up to 2¼ in journal diameter + 0·0005 in for every additional inch or part of an inch of journal diameter. When copper-lead or lead-bronze lined bearings are employed, the basic clearance should be 0·002 in, with the same increments as for white-metal for every additional inch or part of an inch of journal diameter.

Fig. 37. Erosion has caused this failure

In connecting-rod bearings, which are subject to greater impact and reciprocating loads than are main journals, the following recommendations are made. With white-metal, the basic clearance is 0·0005 in for crank pins of up to 2¼ in diameter + 0·00025 in for every additional inch or part of an inch. The basic clearance of copper-lead or lead-bronze linings is 0·002 in and the increments are the same as for the white-metal lined big-end bearings. By selective assembly, the clearance may be reduced, to suit special requirements, to about 0·0005 in per in diameter. This may be necessary, for bearings running at very high speeds, in order to reduce the tendency to change from lamina flow to turbulent flow of the oil.

The empirical formula used by the Glacier Metal Co., Ltd., for making a first approximation of the clearances required is: $c = \frac{\sqrt{s} + k}{100{,}000}$ inches per inch diameter, where c = the clearance, and k is a constant, which ranges from 20 for white-metal to 40 for copper-lead with a lead overlay, and 60 for plain copper-lead bearings. It must be emphasized, however, that the results obtained by the use of this formula are only a rough guide and the figure may be altered to suit considerations peculiar to each application. The figure obtained is a minimum clearance, the maximum one being determined by the build up of tolerances. The tolerances recommended by the Big Six Standardization Committee are 0·0005 in for housings and for journals. The top limit for the journal is the minimum housing diameter, minus twice the maximum thickness of the bearing wall, minus the diametral running clearance. The tolerance for thin-wall bearings is generally 0·00025 in, that is 0·0005 in on the diameter.

The bearing length : diameter ratio is important so far as lubrication is concerned. If the bearing is too short, there is a tendency for the oil to pass out at the ends before being carried completely round the journal. On the other hand, if it is too long, it may be difficult to cool the bearing adequately.

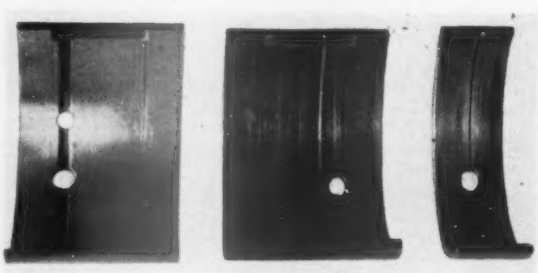


Fig. 39. Foreign matter issuing from the ends of the spreader groove in the white metal-lined shell, on the left, has scored the bearing. The two shells on the right show how damage is localized when no spreader groove is incorporated

The optimum ratio is approximately 0·6:1. However, for intermediate main journal bearings, ratios of 0·3:1 are common. Two main considerations govern the length:diameter ratio. One is the speed of rotation and the other is the space available. For high speed engines, a smaller length:diameter ratio is desirable than for low speed ones, partly in order to reduce the frictional losses and partly because the tendency for the oil to be swept round the journal, rather than to pass out at the ends, is greater.

As a general rule, in all bearings the oil supply should be such as to restrict the bearing temperature to at least 100 deg C below the lowest melting point of the phases in the alloy. When tin-based white-metal bearings are employed, the highest sump temperature should be about 130 deg C, although some engines do run hotter than this. The limit when lead-based, white-metal bearings are fitted is 150 deg C. With copper-based bearing materials, the limit is almost invariably set by the lubricating oil. However, it is generally recommended that sump temperatures of 150 deg C should not be exceeded unless special oils are employed. In gas turbine applications, temperatures as high as 250 deg C have been allowed in the bearings, but under these conditions, as indeed under all others, the variation of strength with temperature of the bearing metal must always be considered.

So far as oil holes and grooves are concerned, the ideal is to have none at all on the bearing surface because they have an adverse effect on the oil pressure distribution over the length of the bearing. The exception to this rule in internal combustion engines is the gudgeon pin bearing, which will be discussed later. Typical oil pressure distribution curves are given in Fig. 36. It can be seen that in a plain bearing, the distribution is approximately parabolic over the length of the journal; however, if an annular groove is incorporated, the pressure tends to be nearly zero over the grooves and the distribution is represented by two parabolas, one each side of the groove. It can be seen from the illustration that the total area of the pressure diagram of the grooved bearing is less than that of the plain one, so that the load carrying capacity of the oil film is also less.

Sometimes it is necessary to furnish an oil transfer passage round a bearing, for instance, to carry oil from the big-end up to the small-end of a connecting rod. Under these conditions it is better from the point of view of the bearing load carrying capacity if the groove is machined in the cap half of the shell only, and the oil is carried away from the ends of the groove by drillings or a groove in the rod. If grooves are cut in both halves of the shell, that in one half is often offset slightly from the one in the other half, in order to avoid a ridge forming round the journal as it wears. Other devices have been adopted, such as machining the grooves at an angle instead of parallel to the end faces of the bearing. However, this measure is not suitable when the length: diameter ratio is small because the ends of the groove tend to come so close to the ends of the bearing that an undue leakage of oil tends to occur.

Spreader grooves are sometimes employed. Some are incorporated to spread oil over the surface, but these are neither necessary nor, because of the tendency for excessive leakage from the ends of the grooves, are they desirable. Others are intended to trap foreign matter that may be in the lubricant and to discharge it from the ends of the groove out of the bearing. As can be seen from Fig. 39, larger particles of foreign matter do not pass out of the bearing with the oil, but are carried round between the shaft and bearing, causing excessive scoring. This tends to spread the scoring over the entire length of the bearing, instead of allowing the particles all to run in more or less the same groove, as is the case when they enter directly from the oil inlet hole.

An unusual type of failure is illustrated in Fig. 37. This is believed to have been caused by erosion, that is, partly by abrasive particles in the oil and partly by corrosion. It would appear that the particles have alternately embedded into the metal during the power stroke, and then freed under a subsequent light load part of the cycle, and moved round and embedded again a little further along the circumference, and so on.

The exception, already mentioned, to the no groove rule is the case of bearings in which the relative motion between heavily laden rubbing surfaces is of an oscillatory nature; as the small-end bushes. In this application, because of the oscillatory motion, oil is not drawn round the pin, as is the case with crankshaft and big-end journals. Moreover, impact loads tend to squeeze the oil from between the surfaces. Under these conditions, because the speed of rotation is small, the cooling requirements are not great and therefore a limited oil supply, such as that afforded by splash, is adequate. However, in some cases, notably in two-stroke diesel units, where the recovery period after each power stroke is too short for the oil film to re-form, it is desirable to machine spreader grooves in the bush, spaced apart such a distance that together, these grooves wipe the whole surface of the pin. Their function is to provide a continuous supply of oil to maintain a film of oil between the running surfaces.

SHOW ISSUE

The extra issue of "The Automobile Engineer", containing a critical review of the developments exhibited at the Motor Show will be available on Wednesday, 25th November, price 3/6. It will deal with all aspects of current design, and will be fully illustrated.

Bearing pressures of up to 6,000 lb/in^2 are allowable in small-end bearings and they are usually of high-tin lead - bronze, or phosphor - bronze. Lined steel bushes are economical. The running clearance is about 0·0003 in, and because of this small clearance it is usual to ream the bushes to size after they have been pressed into the small end. When aluminium alloy rods are employed, it may be difficult to obtain an adequate interference fit because of the differential rate of expansion as between the bearing and its housing.

Some other practical considerations

When, as in certain special applications, exceptionally close clearances are adopted, running-in under light load is essential if satisfactory service is subsequently to be obtained. However, in quantity-produced engines, where normal clearances are incorporated, one hour of running-in is enough. In support of this assertion, experience obtained with reciprocating-type aero engines may be quoted. For these, a bench test of about four hours is given before they are despatched for installation in an aircraft. They may then be called upon immediately to give maximum output under take-off conditions.

With conventional materials and correctly designed bearings, seizure is rarely caused by anything other than dirty oil or by foreign matter introduced during assembly. Occasionally, seizure may be caused by housing or shaft deflections and, in this case, it is usually the edge of the bearing that shows signs of failure. Apart from corrosion, which has already been dealt with, the only other cause of failure is fatigue, and this may arise from two causes. The first is mechanical and the second thermal. Fatigue arising from thermal expansion and contraction is the more commonly met in service, and it usually arises in special circumstances. A private car used in the normal manner may have a relatively small number of starts from cold as compared with a vehicle used for short delivery runs or on similar work. It is under these conditions of frequent reversal of thermal stresses that failure may occur.

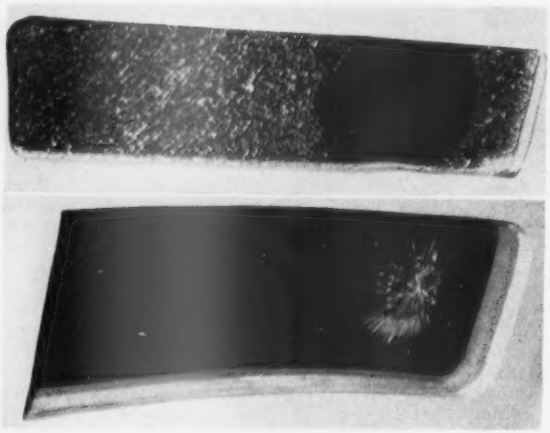
There is a marked difference between the requirements for bearings in private-car engines and those for commercial vehicles. Whereas the private-car engine is dismantled for a rebore perhaps every 30,000 miles, and it is a relatively simple matter then to change bearings if necessary, the commercial vehicle operator using linered engines expects to get a much longer trouble-free life from his vehicle. It is, therefore, the practice to design commercial vehicle power units for rated bearing pressures approximately three-quarters of those adopted private cars.

Acknowledgment is made to Glacier Metal Company Ltd. for providing illustrations and for other assistance in the preparation of this article.

ACCESSORIES AND COMPONENTS

Recently Introduced Products of Continental Manufacturers

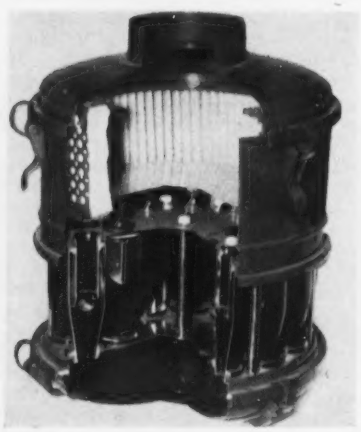
A NUMBER of new accessories were exhibited at this year's Paris Show. Among them was the new Visurit toughened glass for windscreens. This is such a simple innovation as to give rise to the comment that it is surprising it has not been introduced long ago. As can be seen from the illustration, the screen is toughened in such a way that, should a stone hit it, fracture takes place in the normal way, the glass cracking into myriads of very small pieces, which normally remain in position in the frame, but in the Visurit glass, a circular panel opposite the driver remains undamaged, so that his vision is not completely obscured. If, on the other hand, the stone hits the circular panel, star-shaped cracks appear in the panel, but the remainder of the glass remains clear and unaffected. This result is obtained simply by modifying the temperature of the air and the design of the jets directed at the circular panel during the toughening process.



Visurit toughened glass. Above, a clear panel remains when a stone strikes the windscreen or, below, if it strikes the panel, the damage is restricted to a small circular area

The Radiacarter Edac sump for the Simca Aronde has cooling elements on each side

The S.I.A.G.A., Superturbix air filter is also shown in an accompanying illustration. Air enters the unit from between the vertical centrifuge tubes in the lower portion. A slot in the side of each tube directs the air round its interior periphery. Thus, the dust is centrifuged out and drops down into the container secured by means of toggle clips to the base. The cleaned air then passes up a tube that projects down into the centrifuge tube. Thence it passes into a large chamber through a conventional corrugated felt filter to the engine air intake. The top of the filter container is secured by toggle clips so that the felt element may be removed easily for servicing purposes. It is claimed that 95 per cent of the dust is removed by the centrifuge tubes, and that most of the remainder is trapped by the felt element. In view of the fact that the size of the dust particles varies widely as between one locality and the other, it is difficult to see how such sweeping claims can be justified. However, the manufacturers presumably are hardly likely to offer such a complex filter arrangement unless it is, in fact, more than usually efficient.



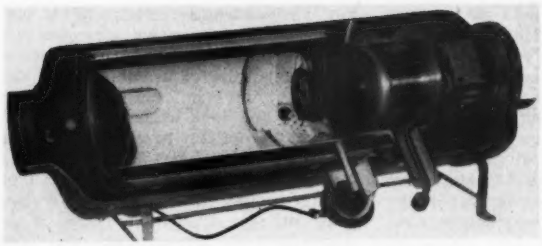
The S.I.A.G.A. Superturbix air filter incorporates a number of centrifuge tubes

Exhaust brakes, although they have not been widely used in this country, are popular on the Continent. The Oetiker exhaust brake is operated by a Bowden cable control. Another cable also secured to the operating lever actuates, in a diesel engine, a fuel cut-off or, in a petrol unit, opens an air inlet between the carburettor and induction manifold. This brake has a two-stage action. First, an arm carrying a steel disc is swung over until the disc covers the main exhaust passage. This leaves a smaller by-pass passage still to be covered. In the second stage, another arm, also carrying a disc on the end, moves over and closes the by-pass port. This second arm incorporates two lugs that register one each side of the first, the cam action of which swings the arm over the by-pass port.

Actuation of the injection cut-off and the air valve on diesel and petrol engines respectively are necessary, of course, to cut off the power when the brake is applied, and to avoid fuel flooding the induction system and cylinders. A two-stage action has been adopted in order that the hot exhaust gases may be cleared out of the system before the brake becomes fully effective. The operating instructions are, therefore, to place the control in the first position and then, after a pause, to move it to the second position.

A new wheel, called the Monobloc-Aspir, is designed to assist the cooling of the brake drums. It is made of cast aluminium and incorporates large vanes and deflectors which are shaped

A Radiacarter Edac sump and oil cooler for the Renault 4 CV



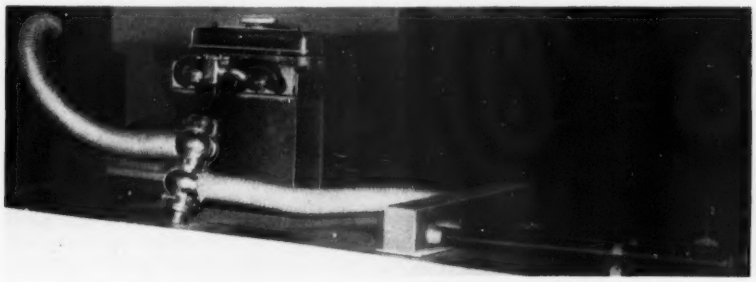
Two blowers, one for the interior heating system and the other for the burner, are employed in the Webasto heater

so as to act as fan blades and eject the air outwards. This direction of flow has been adopted because there is a tendency for a slight build-up of pressure under the wheelarch, and it is better to make use of this pressure to assist the flow rather than to attempt to force the air in the opposite direction against it. On the other hand, an outward direction of flow has the disadvantage that it tends to throw water and mud from inside the wheelarch on to the wheel disc and coachwork.

Engine oil temperatures may vary considerably as between summer and winter and even greater variations exist between the temperatures experienced in units operated in different countries. Most manufacturers are mainly concerned with vehicles for temperate climates, and engines that are perfectly satisfactory under what are generally regarded in this country as normal conditions may suffer from high oil temperatures in some tropical climates.

This has led to the introduction of the Edac cooler, which is supplied for a number of different French cars. The coolers consist of specially designed pressed steel sumps, to which are welded steel blisters fitted with a number of tubes with their axes parallel to the crankshaft axis. The ends of these tubes are welded to the front and rear walls of the blister so that air may pass through them and cool the oil which is in the blister and in the sump. It is well known that great care has to be taken in the construction of welded sumps to avoid seepage of oil through defective welds. There is also a danger of dirt clogging the tubes, but in this unit they are of relatively large diameter and may well be satisfactory. At the worst, an occasional hosing should keep them clear.

A number of heaters were displayed at the Paris Show. Many take their heat from the exhaust system instead of from the coolant water. The disadvantage of units operated by coolant water is that they take a relatively long time to come into operation when the engine is started from cold. There is little doubt that the exhaust-heated type can be less expensive and quicker to become effective, but it has a serious disadvantage in that there is generally a danger of leakage of exhaust gas into the heater system.

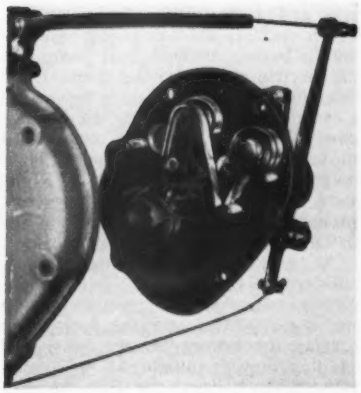


Speed heater system for the Renault 4 CV

In the Hot-Lix heater system a cast aluminium jacket, bottom left, is clamped round the exhaust

The Speed heater unit has been designed for the Renault 4 CV. Air is driven, by the fan, from behind the radiator, where under normal running conditions it is already warm, along a flexible pipe of large diameter and through a cast aluminium jacket round the exhaust pipe. Thence it passes out through another flexible pipe to the heater box positioned transversely under the rear seat. Two long steel pipes extend forward from this box to discharge the hot air underneath the front seat to warm the driver and the front passenger. The rear of the car is heated by radiation from the box and the pipes.

Another heater for the Renault 4 CV is the Hot-Lix heater. This is served by a centrifugal blower driven in tandem in front of the dynamo pulley. Air is drawn into the centre of the blower and thence it passes radially to the collector ring and through a flexible rubber hose connection to the heater jacket clamped round the exhaust pipe. From here, it is directed into the normal Renault heater system.

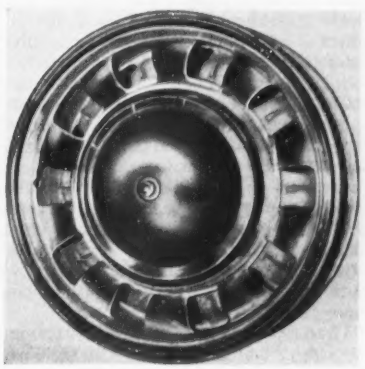


The Oetiker exhaust brake, with the main passage almost closed and the by-pass passage open

Heaters of the fuel-burning type are popular in some countries, particularly for coaches, but also to a lesser extent for private cars. The Webasto unit is an extremely well-designed heater which burns diesel fuel and is intended for use in coaches. Mounted, together with its 2·2 gallon fuel tank, on a metal base, it weighs 48½ lb. Its overall length is 25·6 in, its width is 19 in and height 11·8 in.

The manufacturers state that the No. 65 Webasto unit consumes 1¼ lb of fuel per hour and has a useful output of 6,500 calories per hour. During the same period of time, the 80-watt motor-driven blower delivers about 4,750 ft³ of air and the temperature difference between the air intake and the discharge to the distributor pipes is approximately 100 deg C. It is claimed that the thermal efficiency of the unit is in the order of 80-85 per cent.

The heater consists of a cylindrical housing, at one end of which is the air



Vanes and deflectors on the Monobloc-Aspir wheel draw cooling air over the brake drums

inlet and at the other the air outlet, which encloses another casing containing the burner, blowers, fuel pump and the electric motor driving them. After entering the inlet, the air is driven by a centrifugal blower along an annular passage between the outer casing and the motor and blower casing, which it keeps cool. Forward of this, in the same annular space, is a long heat exchanger ring over which the air passes to the discharge port.

At the end of the inner casing, adjacent to the main air inlet, is the electric motor which drives in tandem the main blower and the fuel pump serving the burner. At the other end of the motor spindle is a smaller blower which draws air from an inlet in the side of the unit, and passes it into the combustion chamber. Housed in this chamber is the burner and also an electrically heated plug used only for starting. When the unit is in operation, the ignited fuel and air mixture is blown against a conical diaphragm and through a hole in its centre. Heat is conducted from this diaphragm to the casing round which flows the clean air passing to the heater system in the coach. The hot combustion gases passing through the hole in the centre of the diaphragm are carried through four large holes in the circumference of the casing into the heat exchanger ring. This ring consists of two concentric tubes between which is formed an annular passage, closed at each end. After passing from one end to the other of this passage, the gases are discharged through a pipe which is welded to its periphery and passes through the outer casing of the unit.

Two thermometers, one in the hot-air discharge port to the heating system and the other in the exhaust port, cause the motor to be switched off automatically should the unit become too hot. The relative dimensions of the two blowers and the porting arrangements are such that there is always a higher pressure in the clean air part of the system than in the combustion chamber and heat exchanger. Therefore, in the unlikely event of the burner casing or the heat exchanger ring becoming eroded to such an extent that leakage occurs, the fresh air will always pass into the burner and there is no possibility of exhaust gases going in the other direction and entering the heating system. Apart from the fact that diesel oil, which is much less inflammable than petrol, is used in this unit, other fire precautions have been taken. The pump and motor are cooled continuously by the main flow of incoming air. To ensure that the fuel pipe lines to the pump are kept cool, they are taken in through the air intake to the blower serving the burner. A drain is incorporated in the pump chamber.

THE PARIS SHOW (*Continued from page* 452)

cars of this type at the Show was the Autobleu, based on the Renault 4 CV chassis. The prototype of this vehicle was designed by Ghia, of Turin, and was first announced in May, 1953. Following its introduction, the French coachbuilder, Figoni, undertook to manufacture it under licence, and it is now marketed by Autobleu.

This two-seater, hard-top coupé has a steel body. In this form there is plenty of luggage space behind the seats so that the disadvantage in this respect of the rear engine has been overcome. Additional space is also available under the bonnet. The only modification to the engine is a special fabricated induction and exhaust manifold, manufactured by Autobleu, to which is bolted a Solex downdraught carburettor with a 32 mm choke.

It is of some interest to compare this installation with that employed in the Antem, which is also a two-seater, fixed-head coupé based on the Renault 4 CV chassis. Both these models can be seen in the accompanying illustrations. Rather more modifications have been made in the power unit installation in the Antem. The compression ratio has been increased, a Fram oil filter is incorporated, and a special inlet and exhaust manifold is fitted, together with a twin-choke, horizontal carburettor. A metal shield has been interposed between the exhaust manifold and the dynamo, and the coil is mounted on a bracket on the frame instead of on the engine. A lead-in for the air intake duct in front of the rear wings has been formed by pressing a channel section in the door panel. This gives it an appearance of efficiency, although in this respect appearances are sometimes deceptive.

Among the small sports two-seaters was the Pichon et Parat Panhard. This gives an impression of being extremely well streamlined, and although the style is undoubtedly sporting, it might not suit all tastes. The whole of the body panel, from the scuttle forwards, together with the bumpers and lamps, is hinged upwards to give access to the horizontally opposed, twin-cylinder, air-cooled Dyna Panhard engine, which is carried on a tubular frame. Accessibility to the power unit and to the front suspension components could hardly be better.

A number of other small cars were shown. Among these was the Rovin, which is still being produced at a rate of 45 to 60 per month. This year, a few modifications have been incorporated. They include higher wings that now sweep straight back above the head lamps, which have been sunk into the wings. This arrangement has improved the appearance of the vehicle by giving it more flowing lines which tend to make it appear longer. Inside, better seats have been provided and a flexible steering wheel is now fitted. Switches for the lamps and direction indicators are mounted on the steering column. The only other modification of importance is that the cables operating the brakes are now of the Bowden type.

An unconventional layout has been adopted for the engine installation and suspension unit of the Nardi. A 750 cm³ four-cylinder, American Crosley engine is mounted behind the double transverse leaf spring suspension system. The power output of this engine is 48 b.h.p. at 5,500 r.p.m. Two Solex carburettors are employed and the exhaust and inlet manifolds are arranged so that below each carburettor riser pipe there is a hot spot. The exhaust manifold is bolted up to the semi-circular balance pipe which connects the siamesed inlet ports. Bolted on top of this balance pipe are the two carburettors. Because of the increased power output thus obtained, a crankshaft made of stronger materials and different pistons are fitted. In addition, the camshaft has been changed.

For the visitor who could spare the time to study detail, there were a great many more features of interest among the other French exhibits. For instance, the blower installation on the Dyna Panhard engine, used in the DB racing car, was exhibited and is shown in one of the accompanying illustrations. Perhaps one of the most ornate examples of the coachbuilders' art was the T.A.I. body on a Salmson chassis. However, such examples are not likely to be taken seriously by manufacturers of quantity-produced cars.

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NEW PLANT AND TOOLS

Trends Revealed by Recent European Developments

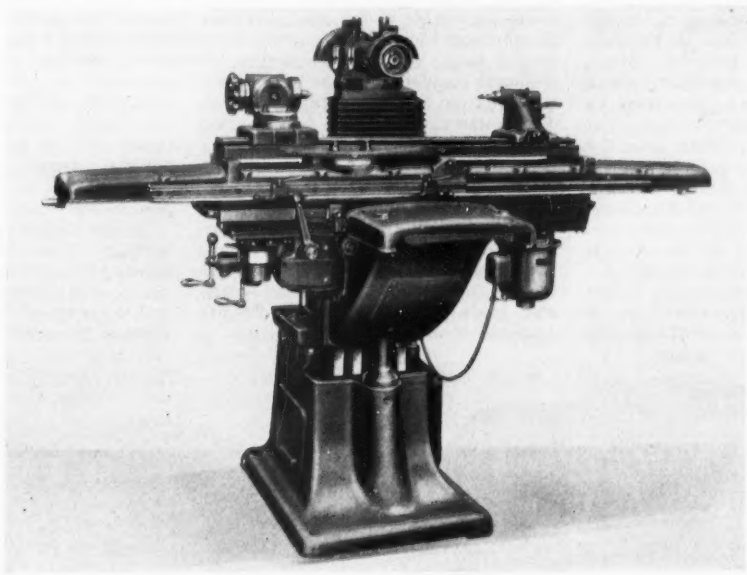
ARISING from the necessity of maintaining the progress already made in industrial recovery, machine-tool manufacturers on the Continent are again able to produce highly competitive equipment. Although the developments—marked by the introduction of new names in both heavy and light machines—have been carried out under extremely difficult conditions, the design of the contemporary equipment is surprisingly similar with regard to both specification and appearance, and will in all probability become closer as more standard components become available.

In general, the trends in design continue along the lines of either hydraulic or electronic operation combined with, wherever possible, some degree of translatory copying control as met in the copy-turning lathe of specialized design. Departures from these more or less accepted developments consist of a specialist approach to particular machining problems that have for a long time been considered to be operations requiring full manual control. Examples in this category include the design of a cutter-grinding machine capable of generating the angle and radii combination of a blade of a multi-tooth cutter at one pass, and the introduction of a practical deep-hole boring machine, each of which can be set for automatic operation. These and similar machines illustrate the line adopted for the avoidance of bottlenecks to sustained production with, wherever possible, the elimination of secondary finishing operations.

Recent exhibitions in this country, Hanover and Brussels have indicated in the most forceful manner possible—by practical working examples—the design changes that have taken place in Continental equipment since 1950, when existing equipment and the availability of material limited the design-development period of the majority of machines. Despite these difficulties, there are few countries on the Continent to-day not producing general purpose and specialized machines of the highest standard.

Schütte tool- and cutter-grinding machine

As the demand from cutting tools becomes increasingly more severe, the question of tool servicing is of great importance. This condition becomes even more important as the ratio of tungsten-carbide tipped tools to high-speed steel tools continues to increase due to the need for reduced machining times. The name of Schütte in the sphere of grinding machines is too well known to require elaboration on basic design, and it is sufficient to say that the company now produce two sizes of the original type of machine—models WU3 and WU4—each embodying a number of improvements. Basically, the smaller machine, WU3, has a longitudinal travel of 19¾ in while the WU4 has a longitudinal travel of 25½ in operated either hydraulically or by the crank-handle method applicable to the smaller machine.



Schütte tool- and cutter-grinder
Alfred H. Schütte, Cologne, Germany

As shown in the accompanying illustration, the existing design of a single, robust column with a cabinet base has been retained to provide a housing for the flange-mounted motor and the lubricating oil circulation pump. A two-speed, 3-phase motor is fitted as standard equipment. The grinding wheel spindle, of a high grade steel and nitrided and lapped on the bearing surfaces, is driven by a pair of spiral gears, one of which is of a fibre material. The upper and larger part of the column forms a container for the spindle lubricating oil, which is pumped up to the spindle bearing by a drive from the vertical shaft of the main motor. Using the principle of a split-bearing, the upper half is under spring-pressure which can be released for thorough lubrication after the machine has been standing idle for some time. This is a feature of the spindle design which allows a variation in adjustment—to the extent that the grinding spindle scarcely can be turned by hand—in order that the highest possible surface finish on the work can be obtained.

Although similar in external appearance, the longitudinal slide differs in the design of the two models. In the smaller version the longitudinal-travel slide runs on a double-row of bearing balls rolling over hardened races, while the larger machine has V-section slideways. For extremely long workpieces, the machines can be fitted with a one-side extended swivel table to increase the distance between centres but not, of course, the grinding length.

The hydraulic control for longitudinal motion is driven by a slow-running pump off an independent motor with separate switch mounting on the cabinet base. This mechanism gives an infinitely-variable table-traverse rate of from 6 ft 6 in to 23 ft per minute. A calibrated dial indicates table speed for repetitive settings. In addition to continuous reciprocation, the control can be set to allow either right-hand or left-hand table stopping. Power feed is re-engaged after a stop by depressing a lever, and direction of travel reversed at any instant by moving another lever.

Walter automatic cutter-grinder

Designed for the automatic grinding of inserted-tooth tungsten-carbide tipped cutters or H.S.S. cutters, the Montanwerke Walter AMS100 machine can grind the complete cutting edge profile at one pass or rotation of the

workhead. Embodying a number of new principles, the machine in effect performs both cylindrical and indexing-grinding operations to produce a combination of radii and angles.

The working units of the machine are supported on a heavy-section cast iron base that encloses the hydraulic equipment, dust extraction plant and electrical switchgear. The workholder slides between the bedways and carries a spindle that is adjustable in the three planes and swivels about a vertical axis. Directly above the workholder slides is the hydraulic drive for the grinding head which permits circular and index grinding. This grinding unit, together with the drive and short wheel-slide, is arranged on a swivel faceplate moving in slideways. With this arrangement it is possible to swivel automatically the entire grinding assembly during the rotation and axial oscillation of the grinding wheel, so that the full cutting periphery of a blade is ground in one operation at a uniform rate. The cutter reverses automatically and indexes by means of a stop-pawl which engages successively with the cutting face of each tooth to ensure not only accurate cutting-circle diameter, but concentricity of the peripheral cutting edges.

In addition, the machine is capable of a variety of specialized grinding operations such as relieving closely spaced teeth with a cup-wheel which can be located relative to the cutter by swivelling the wheel spindle. For grinding lands on the cutting face, the wheel spindle is turned horizontally through 180 deg, and a saucer-shaped wheel is fitted in place of a peripheral wheel. Any cutter between $2\frac{1}{2}$ in and 40 in diameter can be ground on this machine at a time cycle of between 10-20 sec per tooth. An automatic infeed of the wheel from 0·00008 in to 0·00063 in per tooth is provided. The machine is handled in this country by the Elgar Machine Tool Co., Ltd., Hampton Road, Hanworth, Feltham, Middlesex.

Liebherr gear-hobbing machine

The Liebherr gear-hobbing machines made by Hans Leibherr Werkzeugmaschinenfabrik, Kirchdorf/Jller, Germany, can be used for the production of straight and helical spur gears, worm wheels and splined shafts. Equally suitable for production runs or piece-part manufacture, the machines are designed to operate on the orthodox hobbing principle as well as climb-hobbing in order to produce the required finish. Three sizes of the machine are available for cutting gears up to 98 in in diameter. All three sizes have rapid traverses for the hobbing slide and table slide, and a rotary motion for setting up the gear blanks on the machine. The standard head on the smaller machines is suitable for plain, spur and helical gears, while a head embodying a cross-feed can be supplied for worm gears. On the larger machines, one standard head will produce all forms of gears.

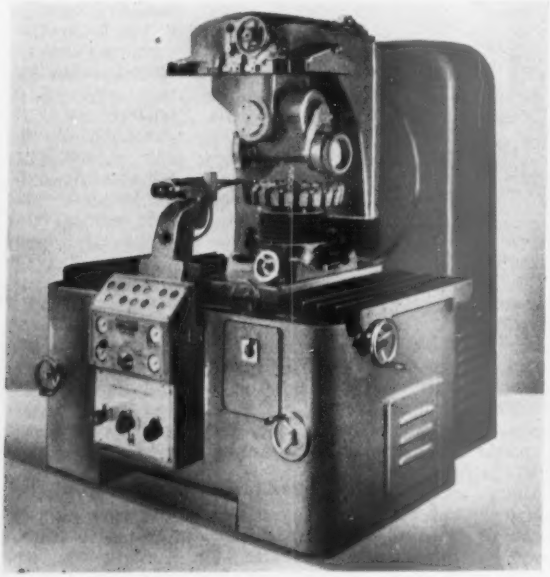
Spindle drive is accomplished by a special worm wheel and a four-start worm, adjustable in the axial direction to minimize backlash. The worm drive to the table also has adjustment to eliminate backlash, and the worm itself is made from fine-grain chilled iron. A double circular slideway is embodied in the table, with a long spigot bearing to permit easy running without the possibilities of inaccuracy of alignment. Both the main drive and the feed motions are infinitely variable and are controlled by direct-reading dials, indicating speed and feed per revolution of the workpiece; cutting speeds and feeds can be varied while the machine is operating.

Pick-off gears are used only for the index and differential units, and pilot lamps indicate where the drives are operating and the stage of the work cycle. With one or two exceptions, all bearings and transmission details are lubricated automatically at about 21 lb/in^2 pressure. Automatic lubrication is also applied to the index worm gear by an oil bath connected to the oil circulating system by way of a fine-mesh filter and magnetic separator. A control panel is fitted to each machine within easy reach of the operator who can, at the same time, observe the machining cycle. This equipment also is handled by the Elgar Machine Tool Co., Ltd.

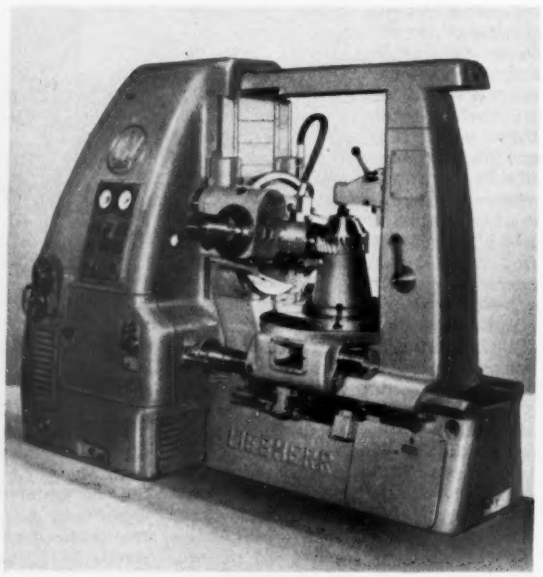
Traub single-spindle automatic

Constructed from a number of unit components, such as twin-bars for the bedways, the Traub automatic is suitable for the production of the usual type of turned part, and for second operation work when using a hopper-feed or manual-feed magazine attachment. Available in three sizes, No. A-15, the smallest, has a $\frac{19}{32}$ in collet capacity with spindle speeds up to 6,500 r.p.m. and is suitable for instrument and electrical parts. The next, model No. A-20, has a collet capacity of $\frac{13}{16}$ in with a maximum spindle speed of 4,000 r.p.m. and is primarily intended for machining screw stock and steels of higher tensile strength. The largest model, A-25, has a collet capacity of 1 in and, with its maximum spindle speed of 4,000 r.p.m., is specially suited for turning free-cutting materials.

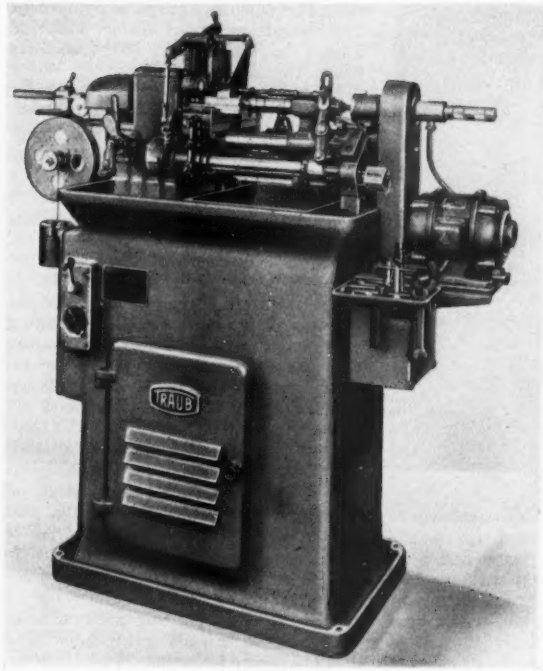
All the models can be equipped with a single - point longitudinal - turning attachment, allowing a turning length up to $2\frac{1}{4}$ in depending upon the shape and diameter of the part. The spindle drive is by vee-belts over a jack shaft



Walter automatic cutter grinder
Elgar Machine Tool Co. Ltd.



Liebherr gear-hobbing machine
Elgar Machine Tool Co. Ltd.



Traub single-spindle automatic
Herman Traub, Wuertt, Germany

from a two-speed three-phase motor to provide 12 spindle speeds. While the machines are designed for use with Index collets, the automatics can be fitted with equipment to use standard Brown and Sharpe collets. The front and rear slides and tailstock are guided on hardened and ground bars, a method which the makers claim has proved to be highly wear-resistant under constant heavy load. The tool support slides are of dovetail section with the usual wedge gibs, and the tool holders have swivel bases. In its standard form, the tailstock has a detachable quill to receive collets.

A separate motor is used to drive the camshafts which have separate cams to operate the slides. The feed can be stopped at any point in the cycle by means of an adjustable friction clutch built into the worm gear drive of the feed mechanism. A built-in change-gear unit allows quick changes of production rate from 38 to 2,400 pieces per hour. Bar stock is fed into the feed tube, that can be swivelled for front loading, by means of a weight-operated plunger with a live plunger head. The bar stop consists of a cam-actuated adjustable swing arm with its fulcrum on the rear guide bar.

Special accessories include a vertical slide, workpiece counter, automatic shut-down, longitudinal turning attachment, centring attachment, high-speed sensitive drilling head, double-head drilling attachment, milling attachment, threading attachment and circular-form tool holder. The centring attachment is used mainly for small diameter drilling, and consists of a fulcrum-supported swivel arm centred about the spindle axis by a cam on the front camshaft. The main function of the double drill head is the production of stepped diameter holes. For this reason the attachment consists of two drill spindles which can be brought on centre by a cam on the front camshaft. A double feeding-cam operates each spindle, and the drilling depth is adjustable through stops, to allow a maximum depth of 1 in.

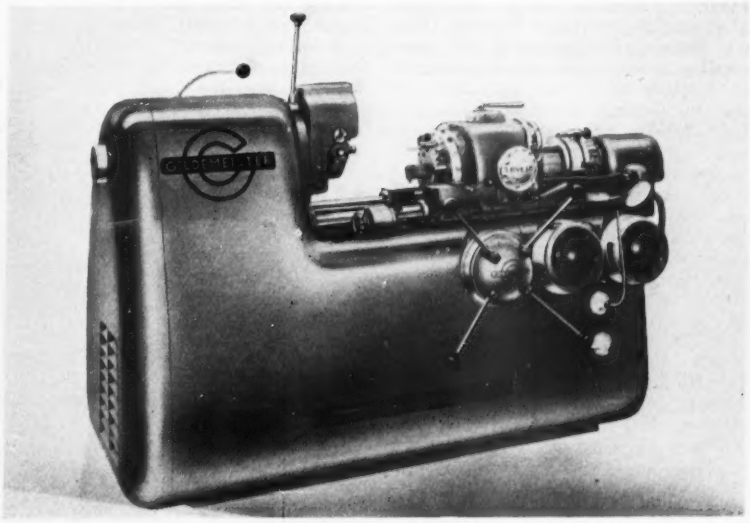
Gildemeister turret lathes

Turret lathes of the Gildematic range are further examples of unit-construction design and pre-selective operation. Both the feed and drive units, together with the main drive motor, hydraulic pump and solenoid control gear can be removed from the machine at the headstock end as units, through the application of a crank handle. Spindle drive is by vee-belts from the gear box, in which the various speeds and feeds are selected, while electro-hydraulic valves are remotely controlled either by the operator or through a sequence-control. These valves in turn regulate the flow of hydraulic fluid to the various controls.

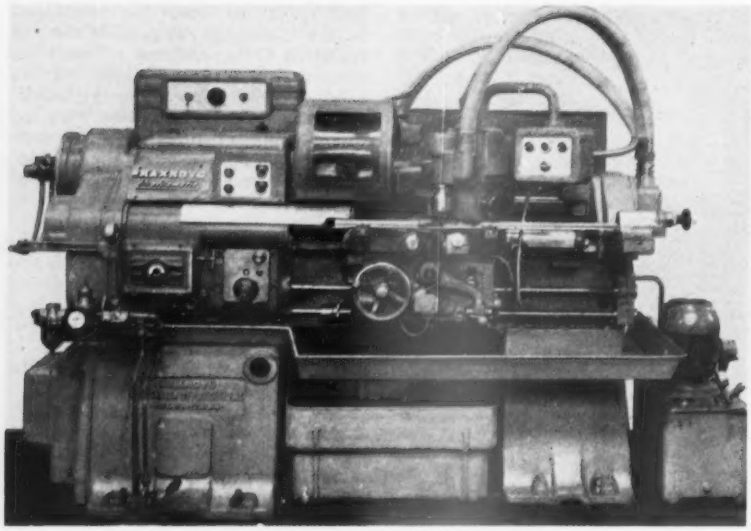
By means of a pre-selection system, both speeds and feeds can be selected for the second operation while the first operation is in progress. Control is effected either automatically or by hand, regardless of whether the spindle and slide are operating. The left-hand wheel on the machine is used to dial-select the spindle speeds from 16 r.p.m. to 2,800 r.p.m. within a control range of 1:180, while the right-hand dial pre-selects the feeds—10 longitudinal and 10 facing feeds within a control range of 1:20. The dial-set speeds and feeds come into operation by pressing the control button in the centre of the hand-wheel. When this button is depressed, it actuates a series of solenoids which in turn control the appropriate set of clutches.

Machine handling is simplified by centralized control with the inclusion of such aspects as the combined stopping, starting and braking through the movement of one lever. Operation of sequence control is basically the same as the hand-operated pre-selection. In this case, the turret head with its 16-tool station represents the selection dial. Control cams fixed on the sequence drum carry out the pre-selection while the electronic control actuating the work cycle is released when the turret is indexed by pressing an indexing lever. The number and position of the control cams is dependent on the workpiece, and they are set in accordance with a table attached to the inside of the drum cover. Once the turret head is indexed, the projections and depressions on the control cams set control pegs to contact limit switches. The hand-operated pre-selection device and the sequence drum method are completely independent of each other to the extent that either system can be used simultaneously or intermittently, without interfering with the other.

A hydraulic collet-type chuck is fitted to the machine. On opening the



Gildematic turret lathe
Gildemeister and Co. A.G. Bielefeld, Germany



Profilomatic double-slide copying lathe
Catmur Machine Tool Corporation Ltd.

chuck, the bar stock moves forward to a pre-stop on the pressure cylinder; the bar length is then precisely limited by the moving turret slide against an adjustable stop fixed to the bed of the machine. Moving and chucking of the bars can be carried out while the spindle is rotating. Machines of the RV series are available in three sizes, models 40, 50 and 63 having bar capacities of $1\frac{9}{16}$ in, $1\frac{31}{32}$ in and $2\frac{1}{2}$ in respectively.

Other production equipment includes a range of automatics in six sizes of four-spindle and six-spindle machines for bar or chuck work. In the larger class of machine is a range of Gildemeister plano-milling machines.

Profilomatic double-slide copying lathe

Representing a new departure in the Maxnovo range of lathes built by Meccania di Precisione, Novara, Italy, the Model B Profilomatic double-slide copying lathe permits the requirements of chucking work to be undertaken by the duplicating principle. Basically, the lathe has two independently operated tool slides working from separate templates. One slide and its template mechanism is located at the front of the machine while the other unit is at the rear. The front slide is usually inclined at 45 deg to the axis of the machine and the rear slide either 60 deg or 90 deg according to the nature of the workpiece.

While the rear slide is cutting one profile—usually the internal or facing operations—the front slide follows the exterior profile or a facing operation. The working cycle is automatic and includes rapid infeed to the point of cutting, cutting feed, feed changes when required, rapid return, start and stop of spindle and coolant supply. The coolant is fed directly through the slides and toolpost and is automatically controlled during a machining cycle.

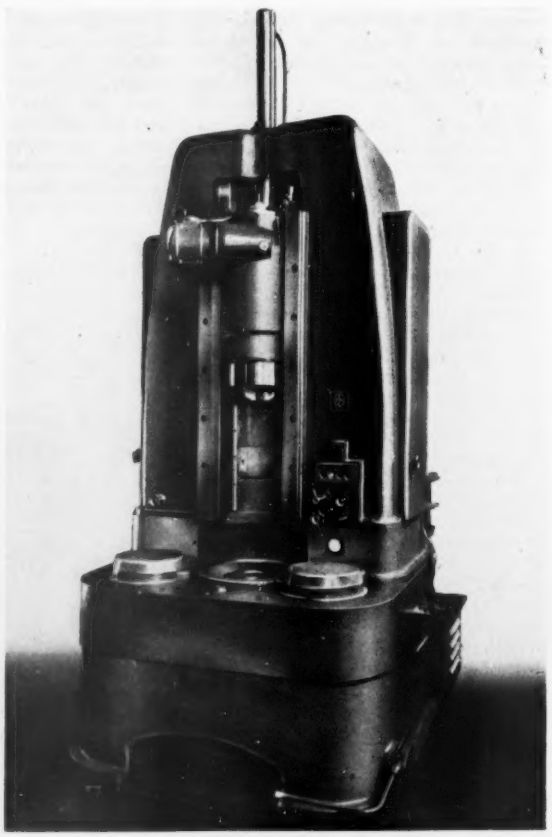
The model "A" version of the Profilomatic lathe has a single copy head and has been improved by design changes which include the addition of a higher spindle-speed range of up to 2,000 r.p.m., and a 20 h.p. main motor. A feature of this machine is the incorporation of a cutting - feed change - mechanism operative during a profiling operation. By means of this equipment it is possible to select either 2 or 3, or 2 or 4 feed ratios during a work cycle; the speeds or feeds can be changed as many times as required.

A variant of the copying equipment is available as a duplicating attachment for shaping machines. In this form, known as model 8321, the tracer head moves in the vertical plane as the table of the machine is traversed across its longitudinal axis. Using this type of equipment allows existing machines to be used in a production line, as the process of reproduction is essentially a copying cycle independent of the skill of an operator. The Maxnovo range of equipment is handled by the Catmur Machine Tool Corporation Ltd., 103, Lancaster Road, London, W.11.

De Roll precision forging machine

The process of close-to-form forging as compared to the upsetting method reduces the material from a large cross-section to a smaller one at the same time that the part is being stretched longitudinally. A new forging technique developed by Gesellschaft de Ludwig Von Roll'schen operates on the basis that the total reduction of the workpiece is achieved by swaging operations to distribute the forging pressure over a number of comparatively small blows. Because of this, the finished shape of the workpiece is not governed by the contour of the dies, but by means of a system of stop plates and templates. In this manner, it is possible to produce a range of forgings from one set of tooling, that is, the changeover from one type of workpiece to another is analogous to the set-up of a turret lathe.

The dimensional accuracy of a finished forging by this method is to the order of $\pm 0{\cdot}008$ in for hot-forged steel between $1\frac{3}{8}$ in and $2\frac{1}{2}$ in diameter. Although the process has for the time being been developed for circular-section workpieces, it is possible with



De Roll precision forging machine
Gesellschaft de Ludwig Von Roll'schen Berne, Switzerland

special attachments, or specially constructed machines to form polygon shapes and splined shafts. The major advantages of the process are a saving of up to 50 per cent in raw material and a shorter working time as compared with die-forging.

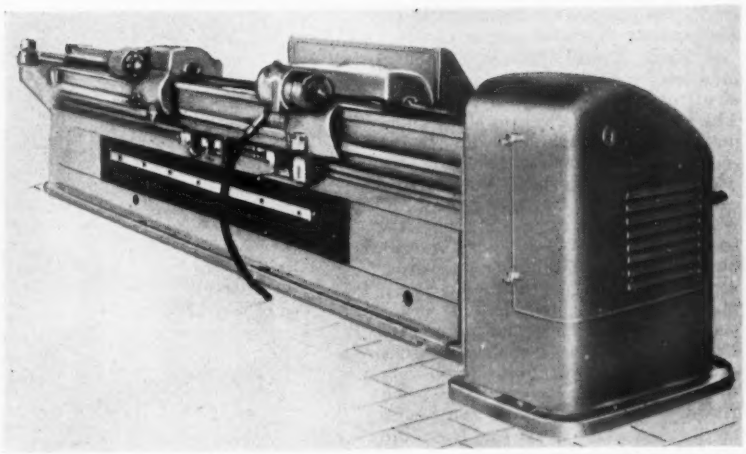
The machine has a maximum forging pressure of 100 tons, allowing forgings up to 3·54 in diameter to be produced with a maximum reduction in diameter of 1¼ in with one set of tools. Up to seven reductions in diameter in one operation are possible with a maximum forging length of 39·4 in.

In operation, a billet is gripped by an air-operated chuck which rotates and feeds it into the forging tools arranged beneath the upper surface of the bed containing the forging box. The forging box is the principal working part of the machine, having three fast-running 120 deg opposed eccentric shafts which generate a swaging motion by guided connecting rods. These shafts are synchronized so that the forging action takes place at three points on the same axis, and on the same plane. The connecting rods are of special design, avoiding any bearing between the eccentric shaft and the small end carrying the forging tools, thus reducing to a minimum the number of bearings taking up the high forging forces.

The eccentric shafts are lubricated by pressurized oil, the forging tools are oil-cooled, and the connecting rod guides are water-cooled in order to carry off heat transferred from the billet. The gearbox drive for the forging box is below the tools and controlled by a sliding clutch mechanism which effects the transfer of torque irrespective of axial displacement. A hydraulic control is fitted to permit automatic operation for the radial setting of the forging hammers according to workpiece diameter, and vertical movements of the chuck according to length.

Forging times depend upon the rate of the advance feed during a cycle of operations, reverse speed, and idling. By means of a throttle valve these speeds can be regulated within a range to 1 to 6 in/sec. The maximum reduction in one forging operation is ½ in on diameter. It is possible, however, to produce the desired diameter in two operations. For the roughing operation, a rapid feed can be engaged, while a reduced feed must be applied for the finishing operation according to the degree of accuracy and surface finish required. The forging of steps requires from 1 to 3 sec per stage.

The setting-up for workpieces requires only a comparatively short time as, in most cases, it is only necessary to adjust stops on a control drum to suit the diameters and lengths required. Special scales are provided for each control drum, giving direct workpiece diameter readings. The weight of a billet for forging can be determined as being about equal to the weight of the finished forging.

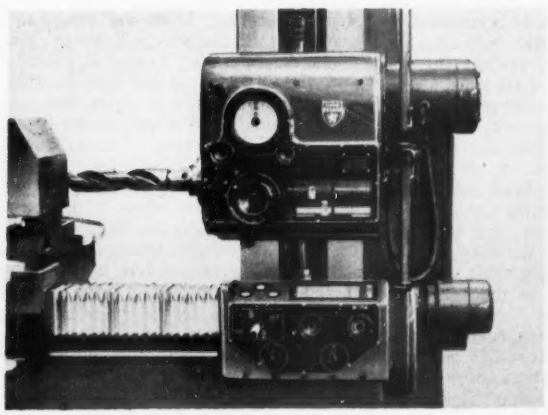


Carlstedt deep-hole boring machine
Wickman Ltd.

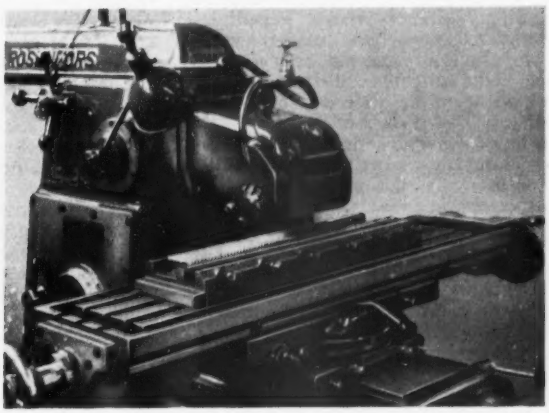
Carlstedt deep-hole boring machines

Following the development in Germany of a deep-hole boring technique wherein the cutting oil is pumped around the outside diameter of the boring bar and removed with the swarf through the centre, machines are now in production to make use of this process. It allows pierce-boring or counterboring penetration rates of at least double those achieved by existing equipment. The four Carlstedt machines in various bed lengths are of the most recent design embodying the latest technical improvements resulting from collaboration with Heller, of Bremen - Mahendorf, Germany, the manufacturers of the boring head and accessories. Capacity of the range covers boring depths from 3 ft 7 in to 15 ft 7 in, and diameters from ¼ in to 2 3/16 in from the solid, or 4 7/16 in by trepan-boring or counterboring.

The technique is dependent upon high spindle power which, in the largest version of the machine, is a total of 70 h.p. Features common to all the machines consist of a work-clamping slide having a double female-cone clutch for self-centring the workpiece by either automatic or manual loading. The cones are serrated to allow the workpiece, which for this method must have a mating taper at each end, to be held without slip. One cone—the headstock member—remains



Pégard boring and milling machine
Marcel Pégard, Andenne, Belgium



Rosenfors milling machine
A. B. Rosenfors Bruk, Foundry and Machine Works, Rosenfors, Sweden

axially stationary while the other can be advanced or retracted pneumatically.

A stable, almost uniform, feed-rate, infinitely variable from ¾ in/min to 40 in/min, is obtained hydraulically. The system is arranged to allow automatic rapid retraction if the thrust required for machining the workpiece exceeds a pre-set value. A machining cycle is initiated by a single control which, in the largest model, starts up sequentially the 15-30 h.p. coolant pump motor, the 38 h.p. spindle drive motor and a 2 h.p. hydraulic pump motor. At the termination of a complete boring cycle, the motors are stopped after the boring slide has extended to the open position allowing the workpiece to be removed. To permit easy work-handling, the spindle of the machine is off-set from the centreline of the machine so that a conveyor or hopper-tlue bar feed can be fitted.

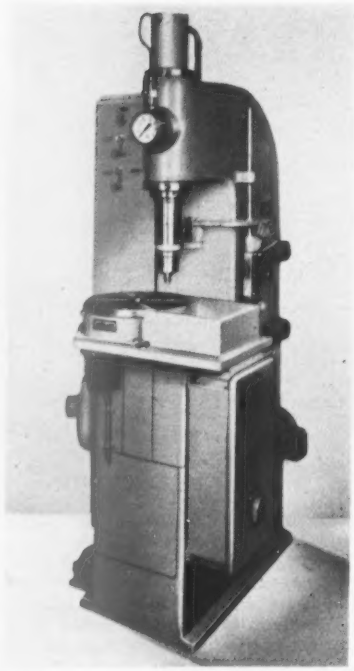
In view of the nature of the operation and the impossibility of visual observation, it is essential to have a full and instantaneous control over the cutting conditions, which call for the use of coolant at pressures of between 200 and 850 lb/in^2, with a circulation rate of between 20 and 40 gal/min. This objective has been achieved by grouping all controls in a console-type desk. The main controls provided are for rate of feed, spindle speed, hydraulic pump, and work clamping. These basic controls are used in conjunction with a comprehensive set of instruments comprising ammeter, boring-thrust gauge, work-clamping, coolant, and filter pressure gauges, a depth-of-bore gauge, and a thermometer.

The importance of these controls and check readings becomes apparent when it is appreciated that the average surface finishes now claimed by the manufacturers for finish boring operations are 0·3 to 1·0μ. Manufactured by Maskinfirma R. L. Carlstedt, Mälarhöjden, Stockholm, Sweden, these machines are now handled in this country by Wickman Ltd., Coventry.

Pégard boring and milling machine

To complete a range of universal boring machines, Marcel Pégard has introduced two new models which, while built up from the same assembly of bed, uprights and table, can be equipped with different headstocks. The first of these models—AF60—has a headstock with a fixed spindle bored to American taper No. 50. While remaining a boring machine, it is especially intended for milling operation. Model U60 is fitted with a traversing spindle headstock. This machine is a universal borer similar to the larger models, U80 and U100, already in production. Both variations of the No. 60 have infinitely variable spindle speeds from 14 to 1,800 r.p.m. and infinitely variable headstock speeds from 0·067 in to 4 ft 11·06 in/min.

Automatic slow or rapid feeds are selected by the movement of a lever fitted with a spring catch. This catch allows an intermediate passage from the slow speeds to the rapid feeds with automatic return to the first feed when the catch is released.



Müller automatic-indexing press
Elgar Machine Tool Co. Ltd.

Rosenfors milling machines

The Rosenfors universal milling machine type RFU and the plain version type RFE have their columns cast integrally with the bed to provide a rigid structure of conventional design. Spindle and table have individual drives. The main motor, 5-7½ h.p., is located in the column on a platform vertically adjustable for belt-tensioning, while the table is driven by a 1½ h.p. motor in the right-hand portion of the knee, as viewed from the front of the machine.

The gear system for the spindle drive is enclosed within the column. Spindle speed changes are obtained by means of a crank-handle connected to a dial to give a positive indication of speed. Table feeds operate in six directions by means of separate levers so arranged that they are moved in the direction of feed required. A rapid traverse is included, and this is operated by a multiple-disc clutch on the right-hand side of the knee. An extra feed-shaft for transmitting the drive to the right-hand end of the table is intended for various auxiliary attachments, such as a rotary table, as well as an indirect drive to the table for milling curves.

The table is of robust design and is surrounded by a coolant channel. Double strainer-type filters are provided in the coolant return pipe. Two sets of longitudinal feed-nuts are fitted to the leadscrew, one of which is adjustable from the front of the carriage to eliminate backlash and allow the machine to be used for "climb" milling.

The electrical connections are contained in a built-in cabinet. This equipment comprises the necessary contactors and main switch, in addition to a mains transformer, enabling the same equipment to be used for all standard voltages by merely changing the position of the tappings. Extra accessories include a vertical milling attachment, having a 1:1 gear ratio with the horizontal spindle, with 360 deg adjustment in the vertical plane. A universal head which is an extension of the vertical head allows 360 deg adjustment in the perpendicular and horizontal planes of rotation. The rotary table is operated by worm gearing driven from pick-up gears from the feed extension. When the power drive is used, the feed-rate at the periphery of the table is equal to the longitudinal feed of the table.

Müller automatic-indexing press

Müller single-column oil-hydraulic presses of 4 ton to 40 ton capacities in a range of six sizes as standard, can now be supplied fitted with a new fully-automatic, electrically operated indexing table. The combination of the machine with the automatic indexing table enables a higher rate of production for many components. The presses operate with a high degree of safety as the loading position is not directly under the ram of the press and is, therefore, away from the danger area. The rotating table indexes automatically at 60 deg, 90 deg, 120 deg or 180 deg each time the ram returns to its top position. Immediately the table has completed its movement the ram automatically commences a new cycle. The number of positions indexed by the table can be varied by changing the controlling cam. The unit is so constructed that, after indexing, the component is accurately positioned under the centreline of the ram.

The press is supplied with an automatic indexing table having a special control panel fitted on the left-hand side of the machine. This provides either semi-automatic or fully automatic operation. With the semi-automatic system, the ram makes one cycle when the operating button is pressed, and the table is indexed one position. On the fully automatic cycle, the ram and table operate continuously until the button is pressed a second time. With either the semi-automatic or fully automatic cycle, the press can be arranged to return when a predetermined stroke length has been reached, or a pre-set pressure attained, or a predetermined pressure has been maintained for a set period of time.

The ram can also be made to dwell for a set length of time at the top of the stroke. By using this dwell, the time cycle can be arranged to suit the loading time needed. The Elgar Machine Tool Co. Ltd., Hampton Rd., Hanworth, Feltham, Middlesex, are the agents for these machines.

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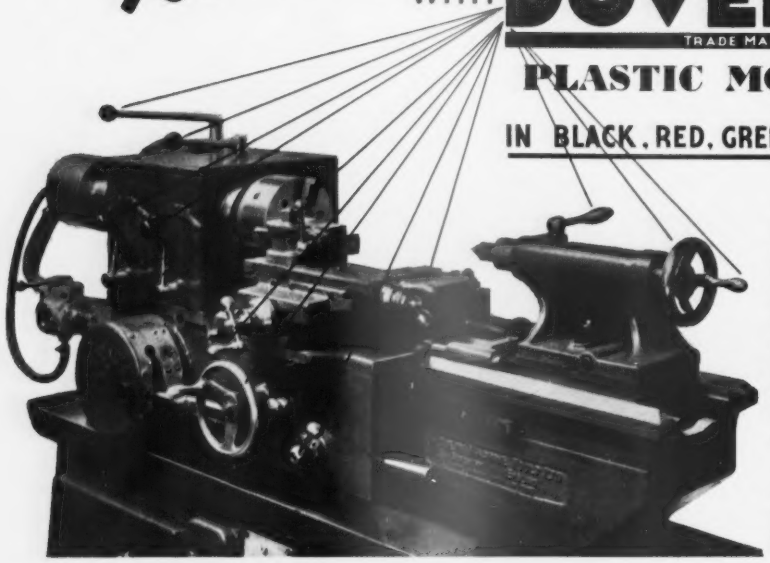

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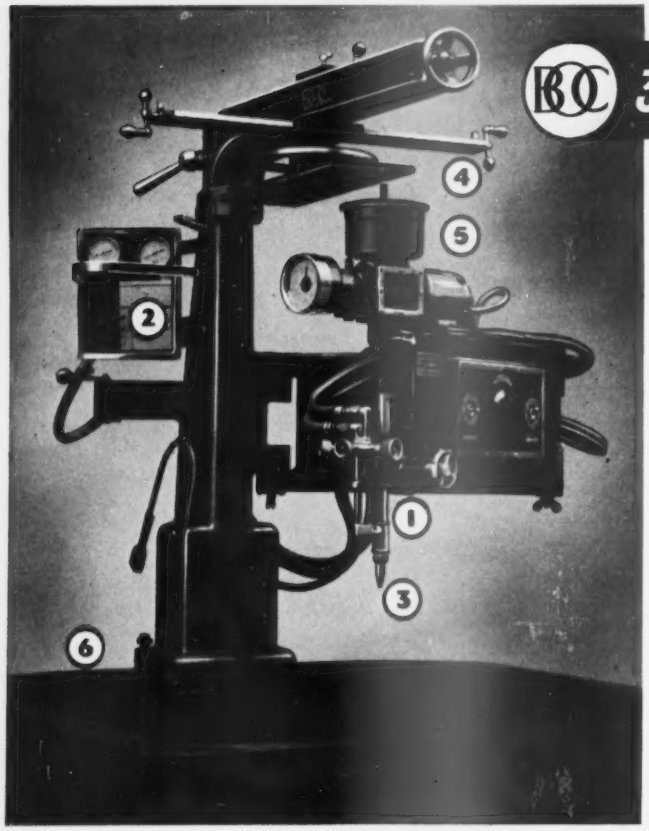

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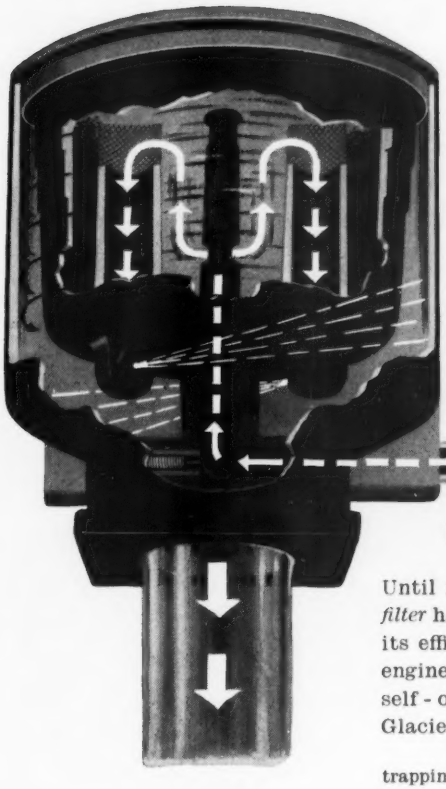

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Too simple to work? The proof lies in working efficiency. The Glacier Centrifugal Oil Filter has been submitted to exhaustive tests and cannot be faulted. If oil is cleaned by passing through a filter medium on the principle of a strainer, efficiency at best is relative: *the Glacier Centrifugal intercepts particles that will pass through the mesh of the finest strainers in use.* Many strainers, moreover, progressively lose efficiency as they become clogged with the dirt they are trapping until the ever more restricted oil-flow and loss of pressure bring a by-pass valve into play which feeds dirty oil to the bearings. *The Glacier Centrifugal Oil Filter maintains high efficiency and constant flow.*

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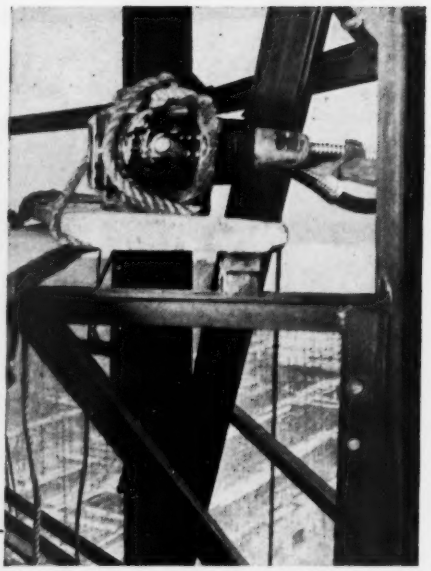

Illustration shows Newton Victor Raymax 140 kV. Industrial X-ray Unit lashed in position for radiography of welds during construction of the welded heat-storage tower for the Pimlico District Heating Scheme.
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ILFORD INDUSTRIAL X-RAY FILM TYPE A
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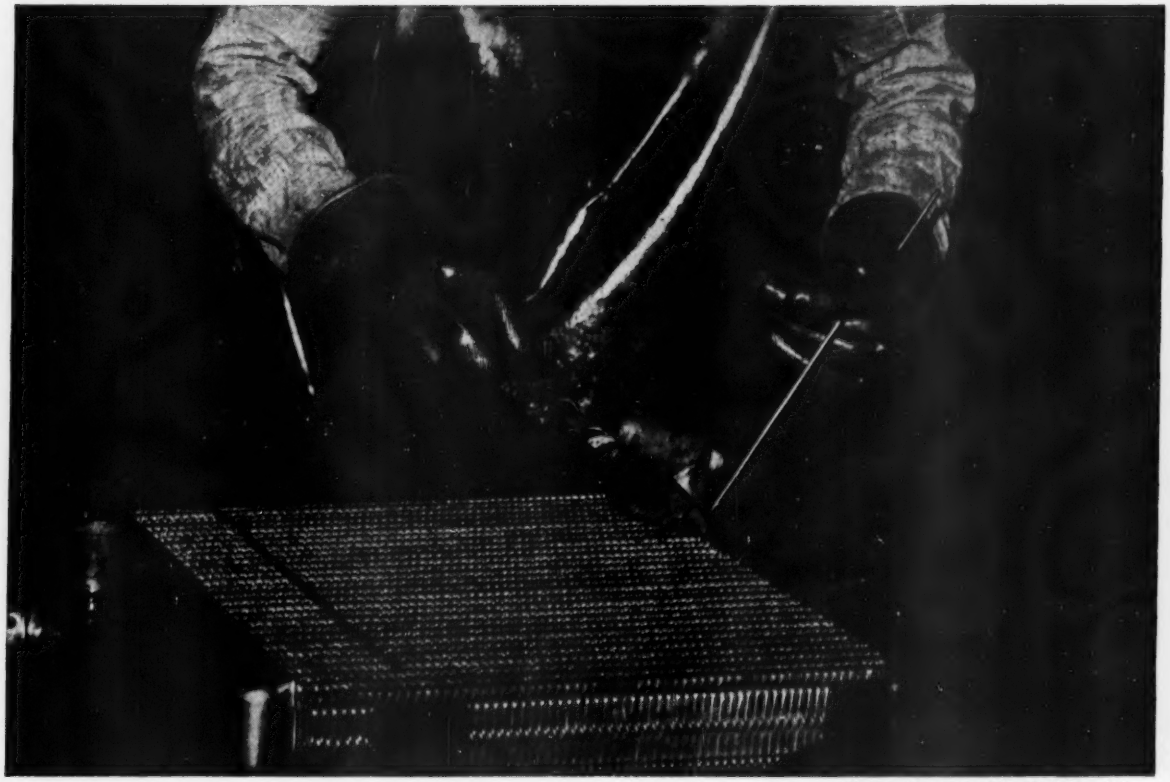

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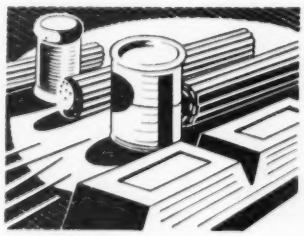

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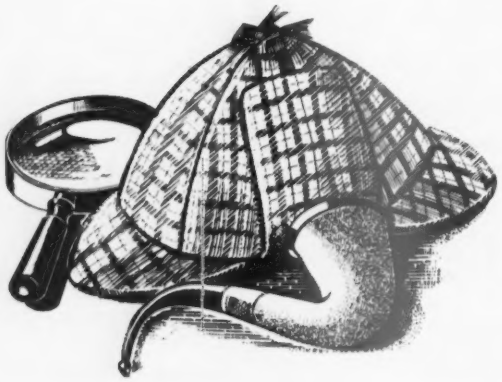

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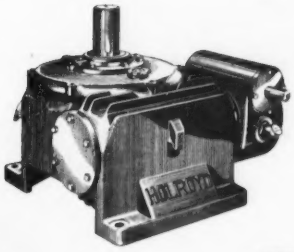

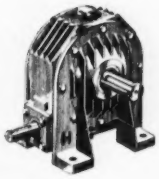

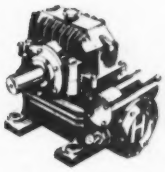

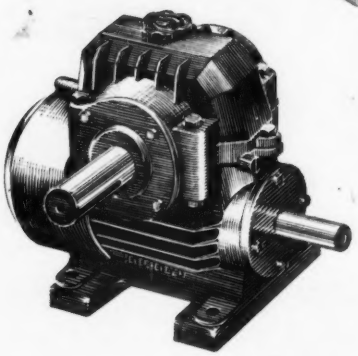

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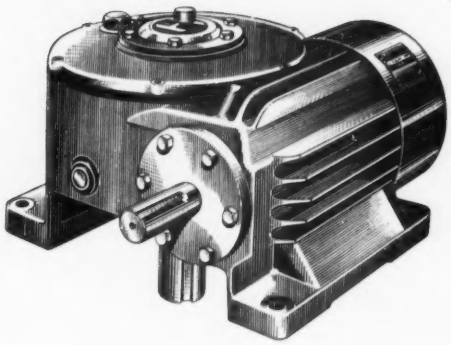

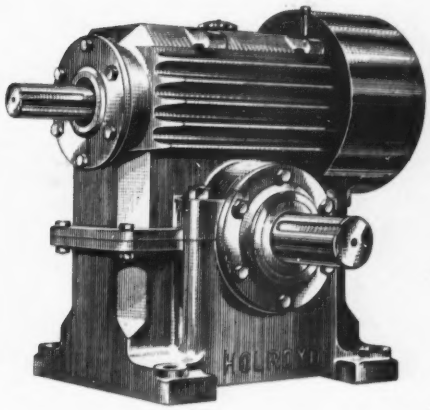

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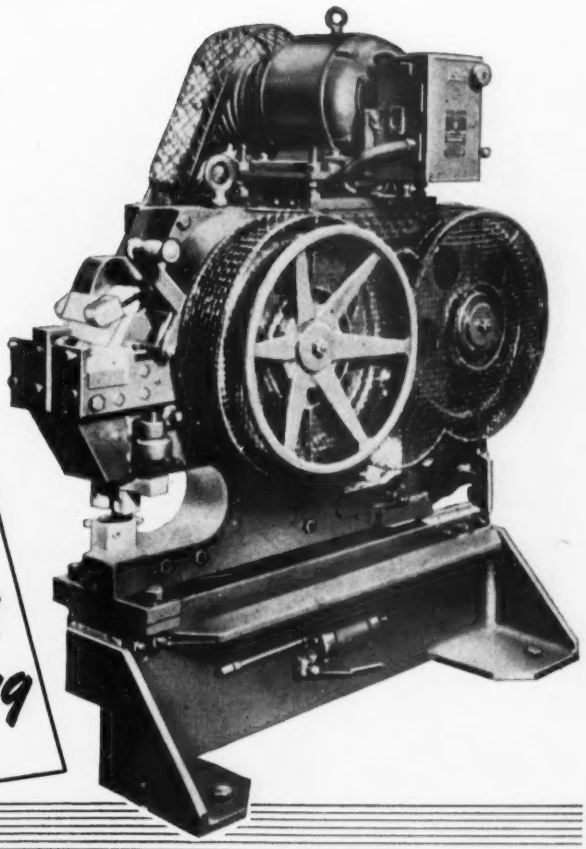

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D.E.P.S. 24

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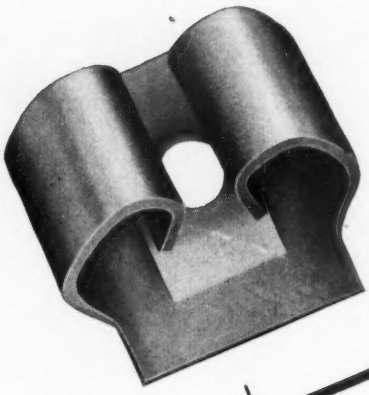

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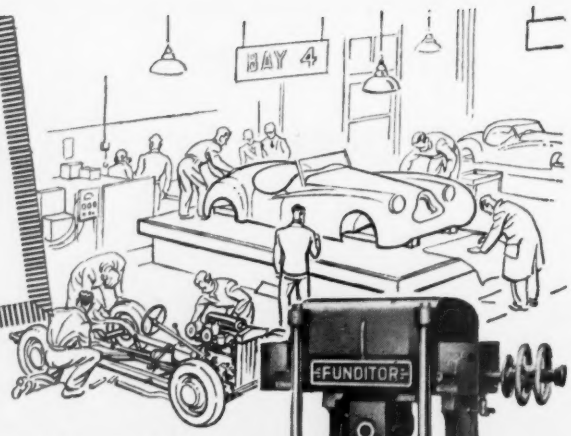

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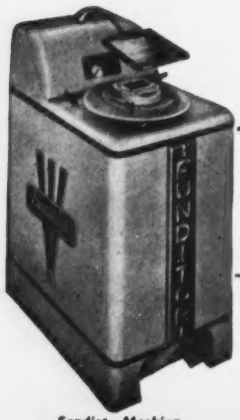

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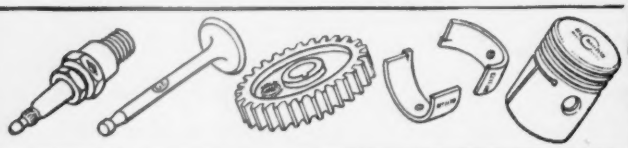

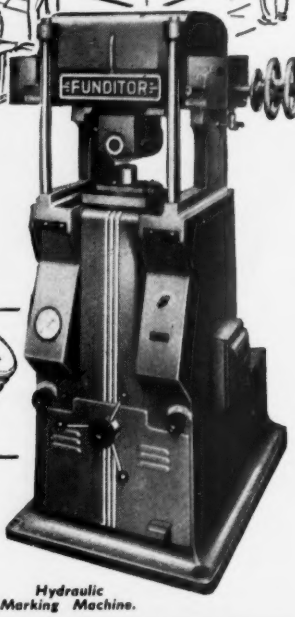

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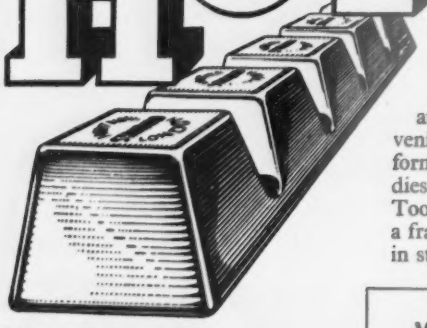

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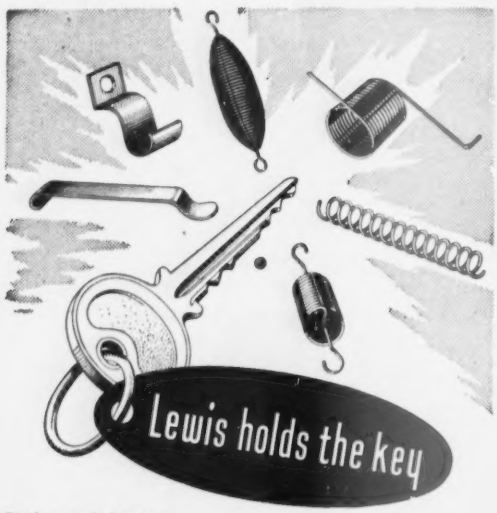

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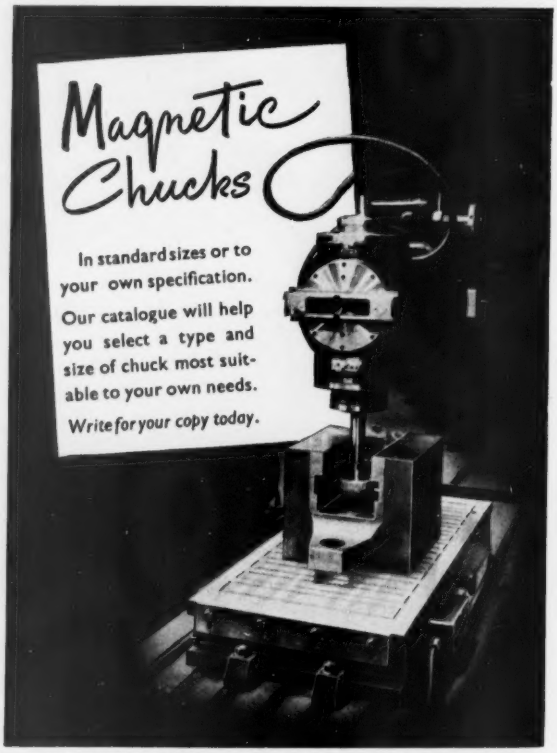
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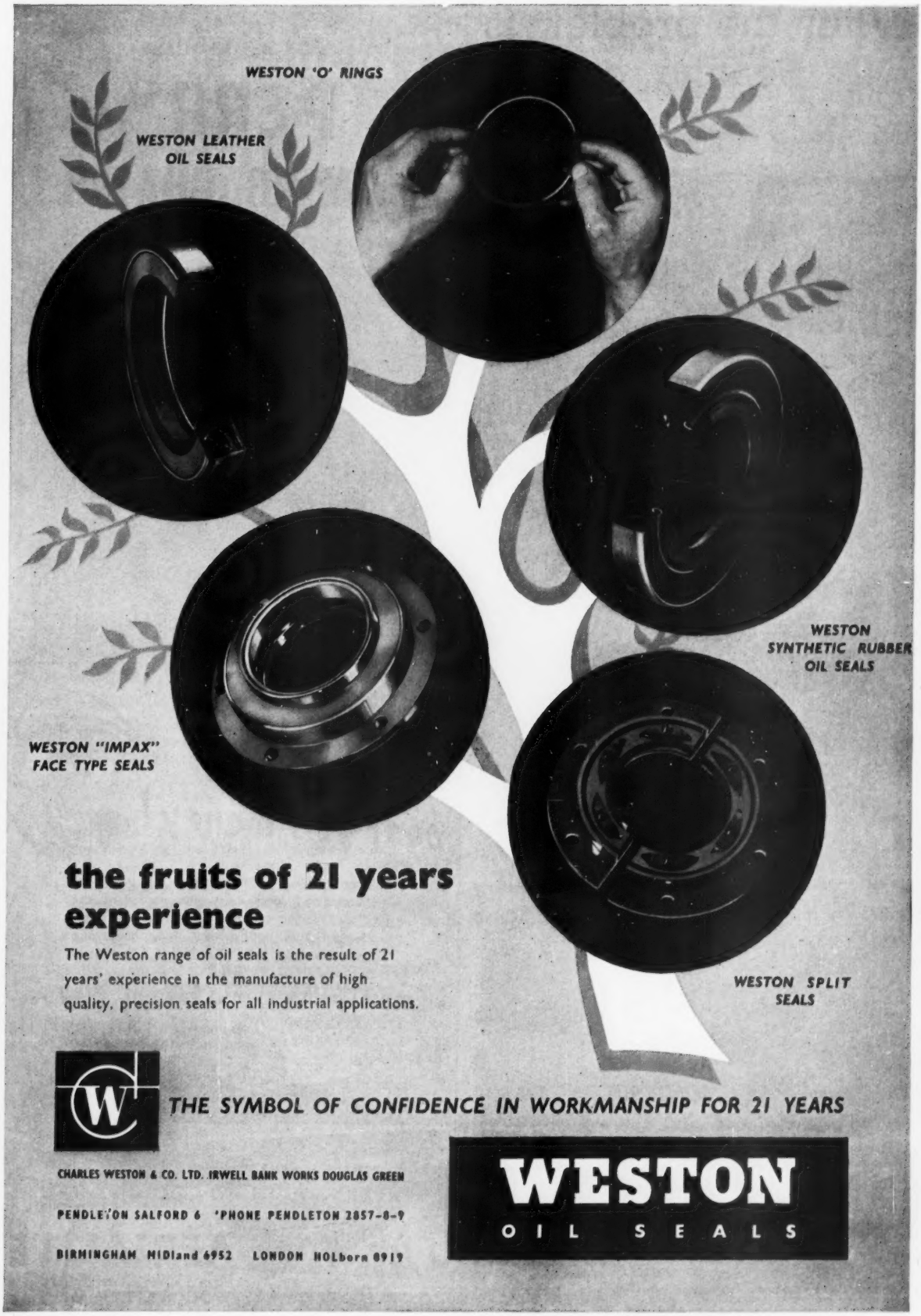
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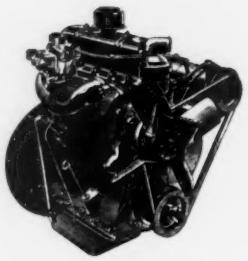

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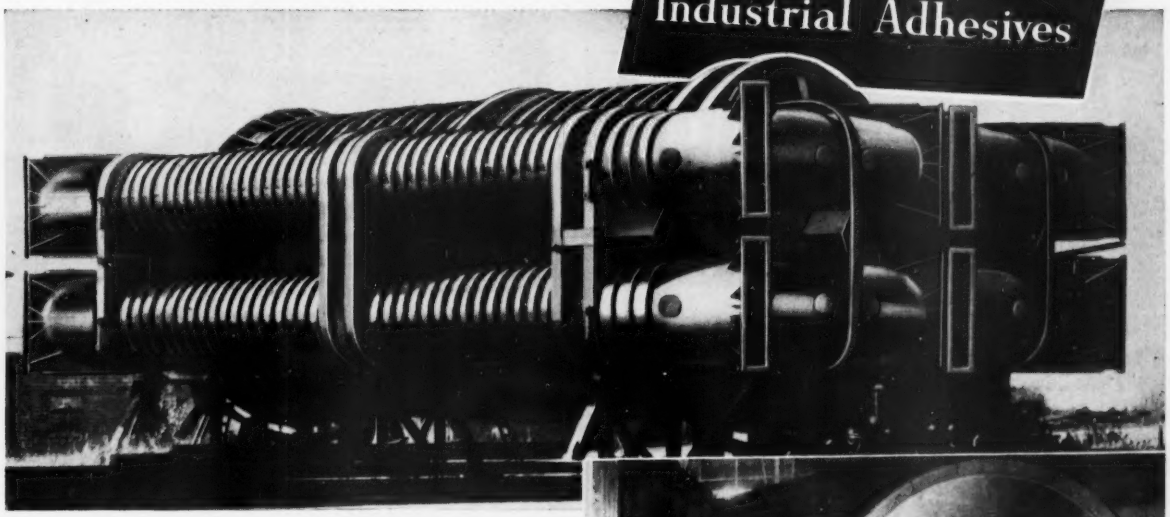

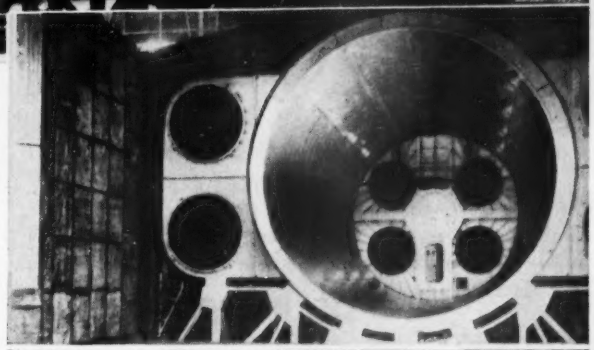

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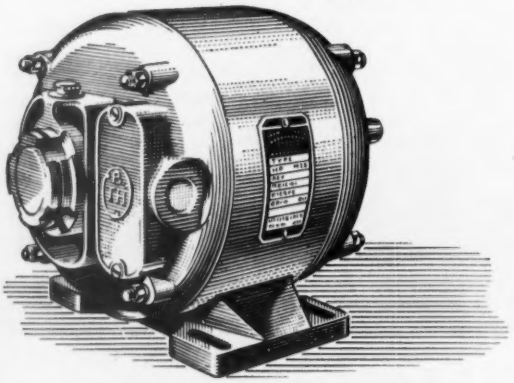

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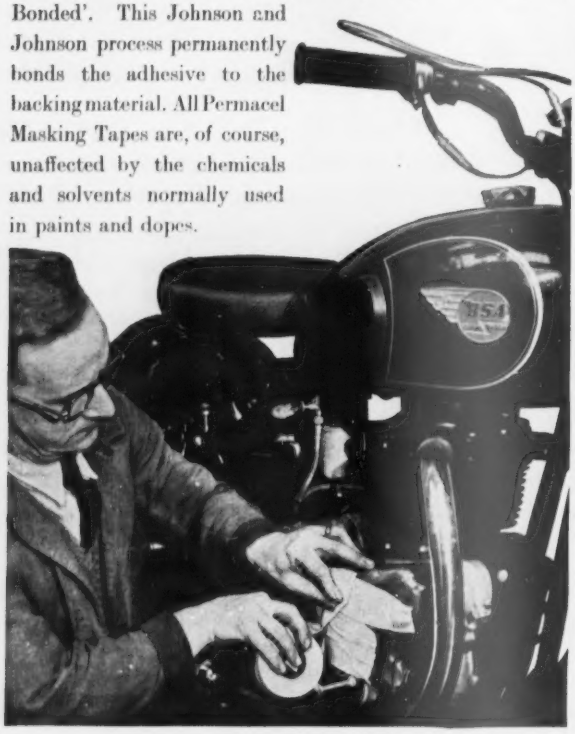

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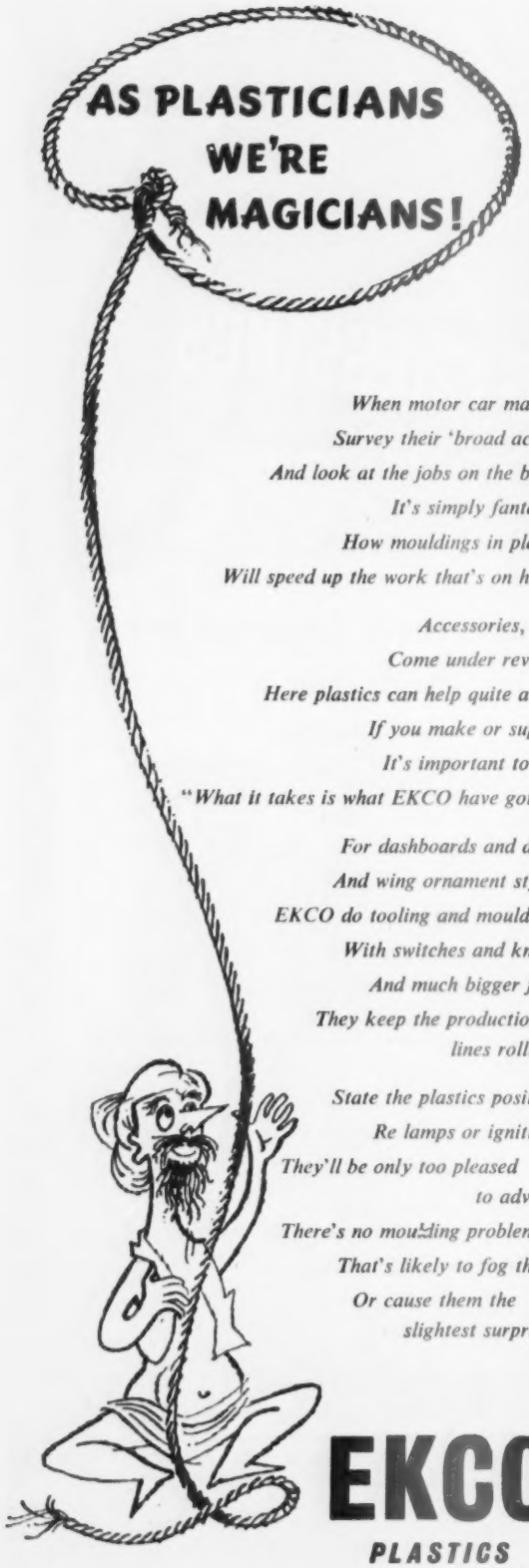

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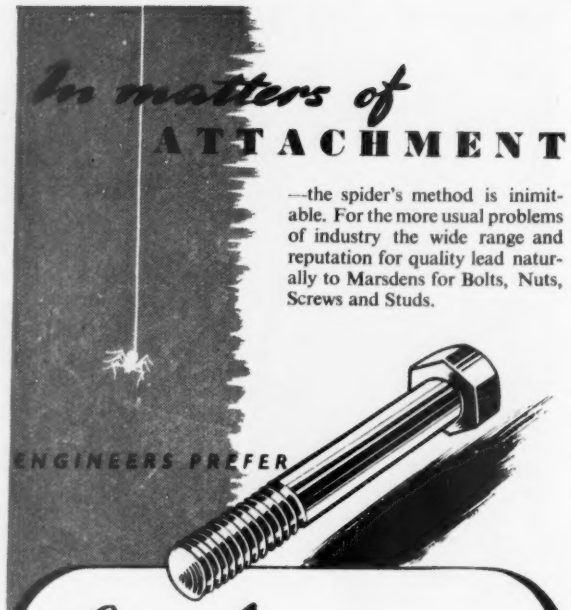
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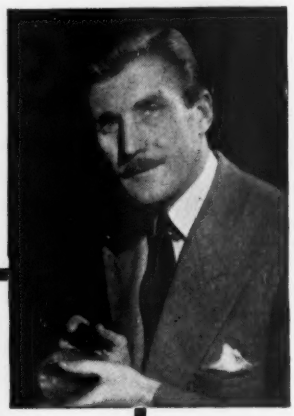

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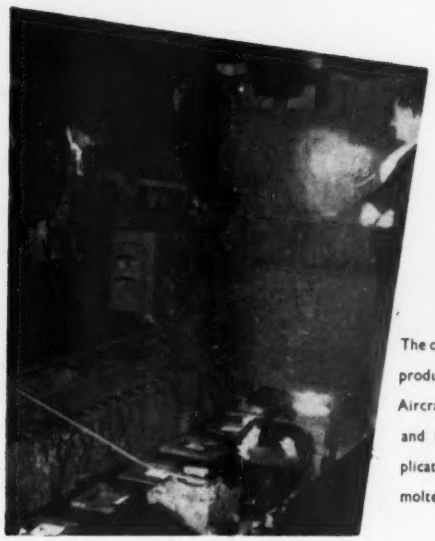

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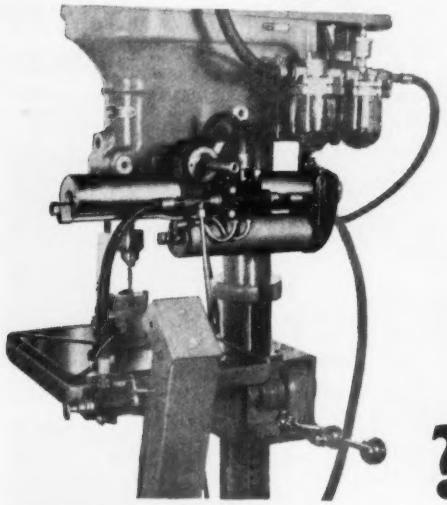

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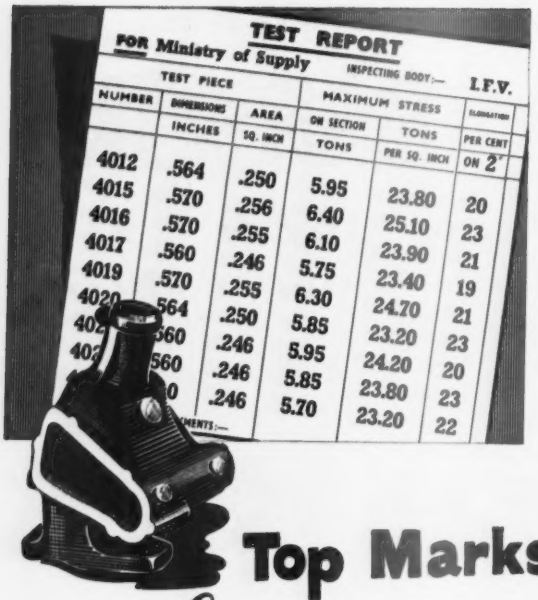

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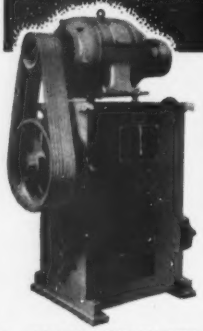

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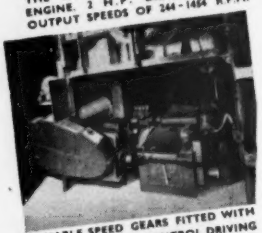

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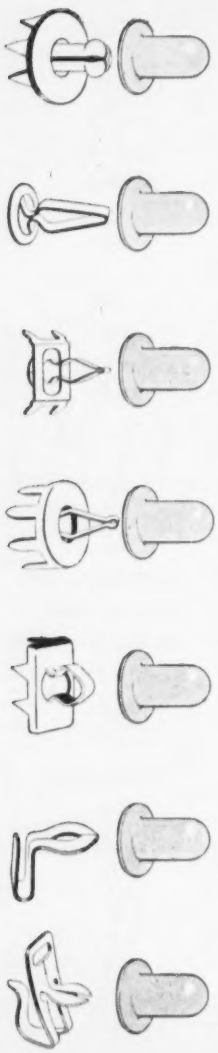

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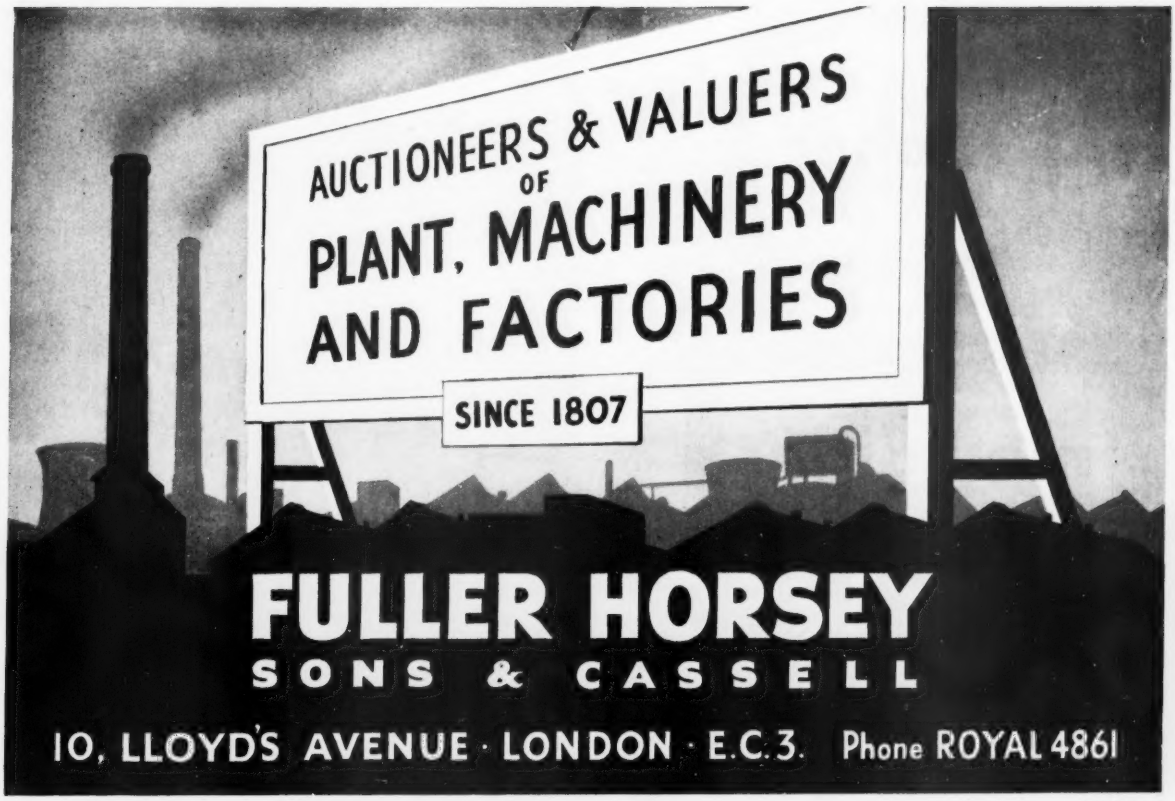

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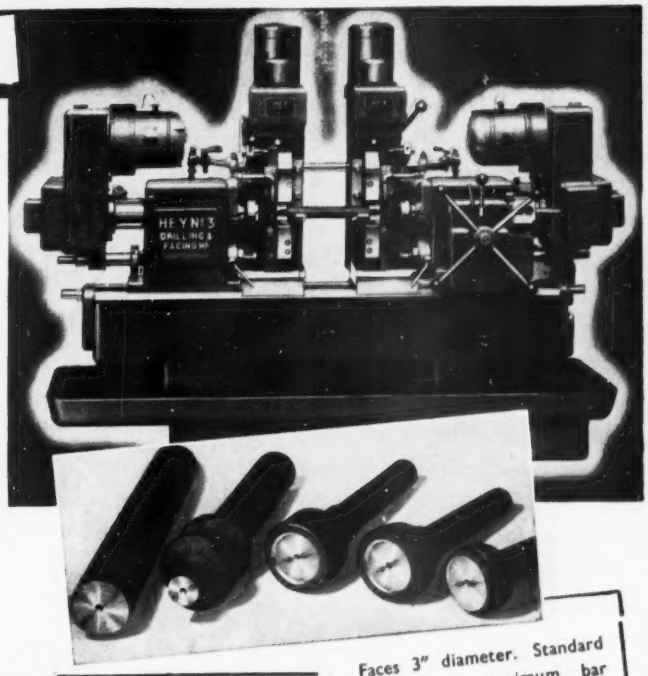

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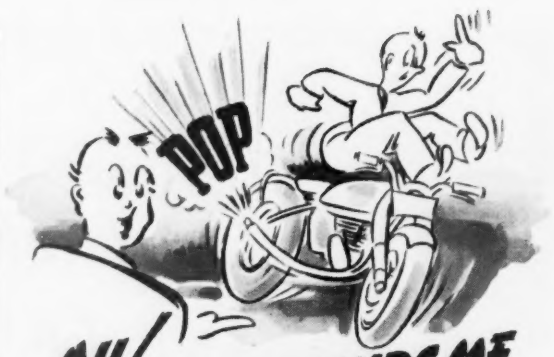

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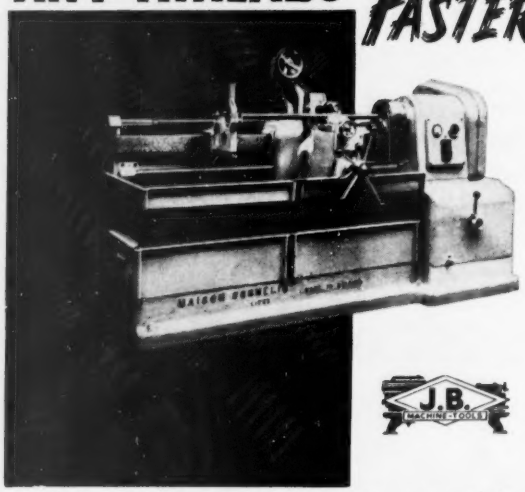

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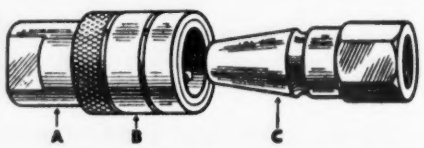

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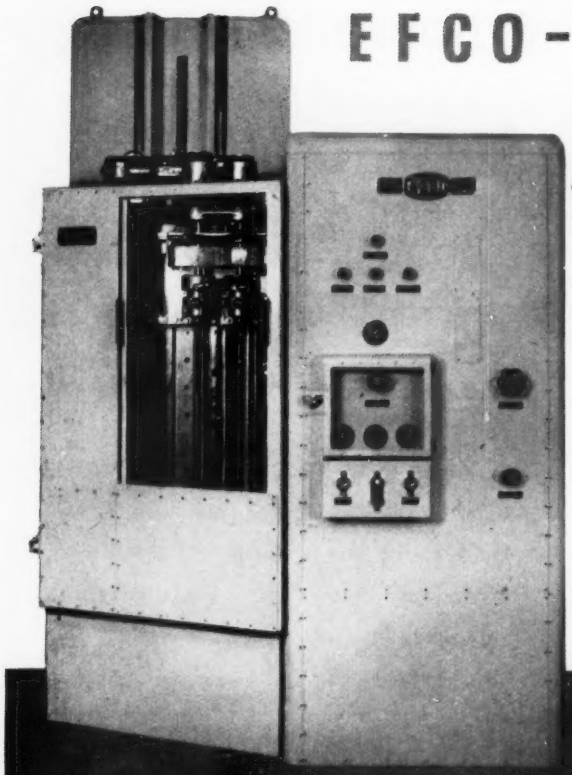

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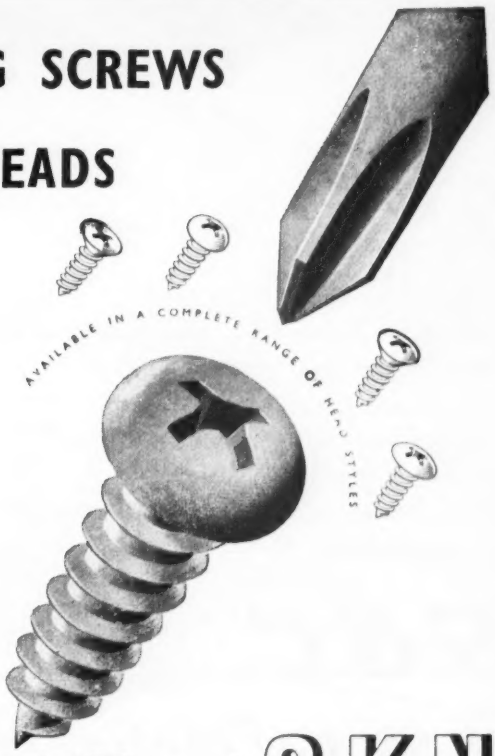

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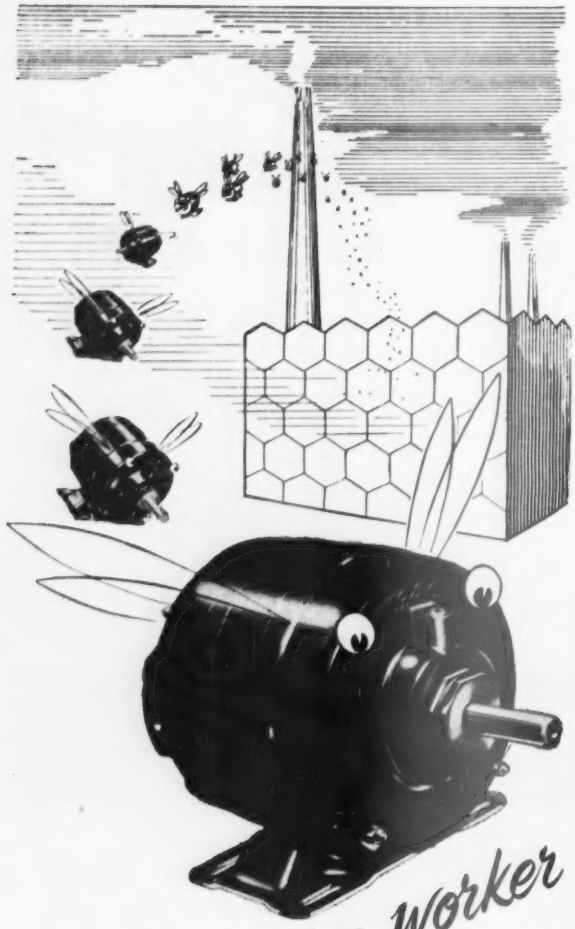

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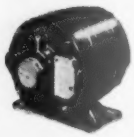
G.E.C.  ***Fractionals***

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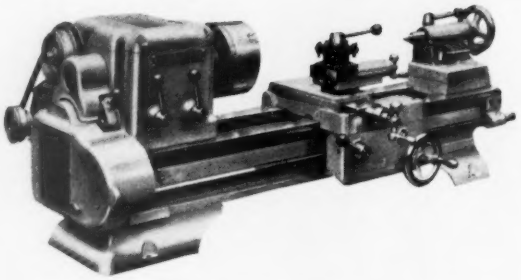

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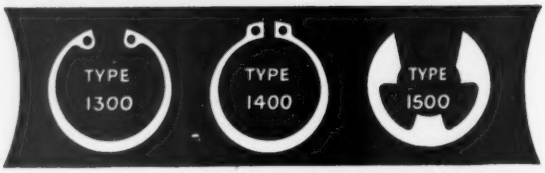

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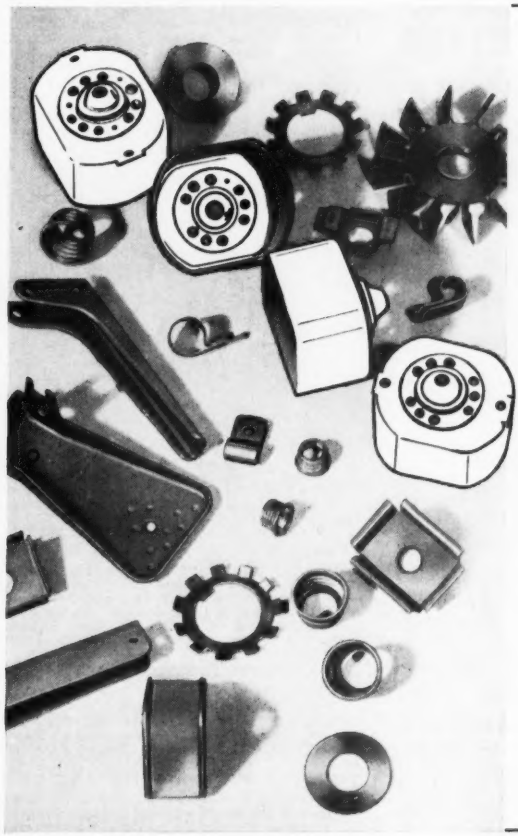

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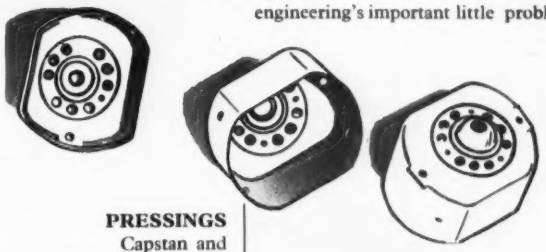

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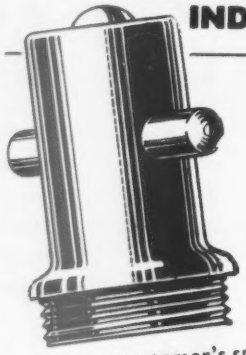

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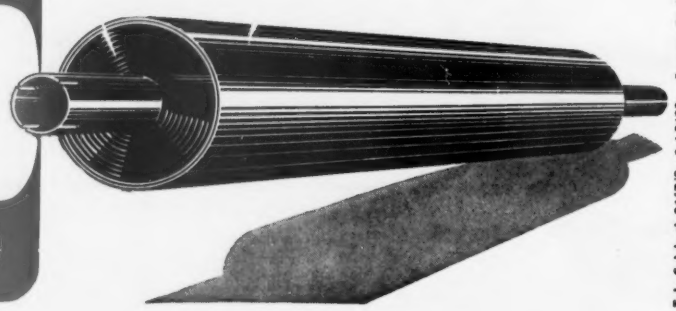

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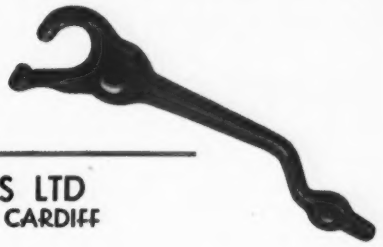

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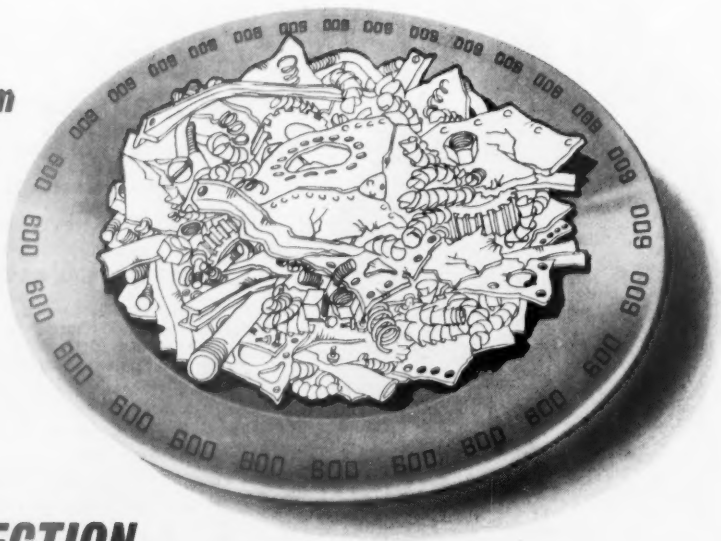

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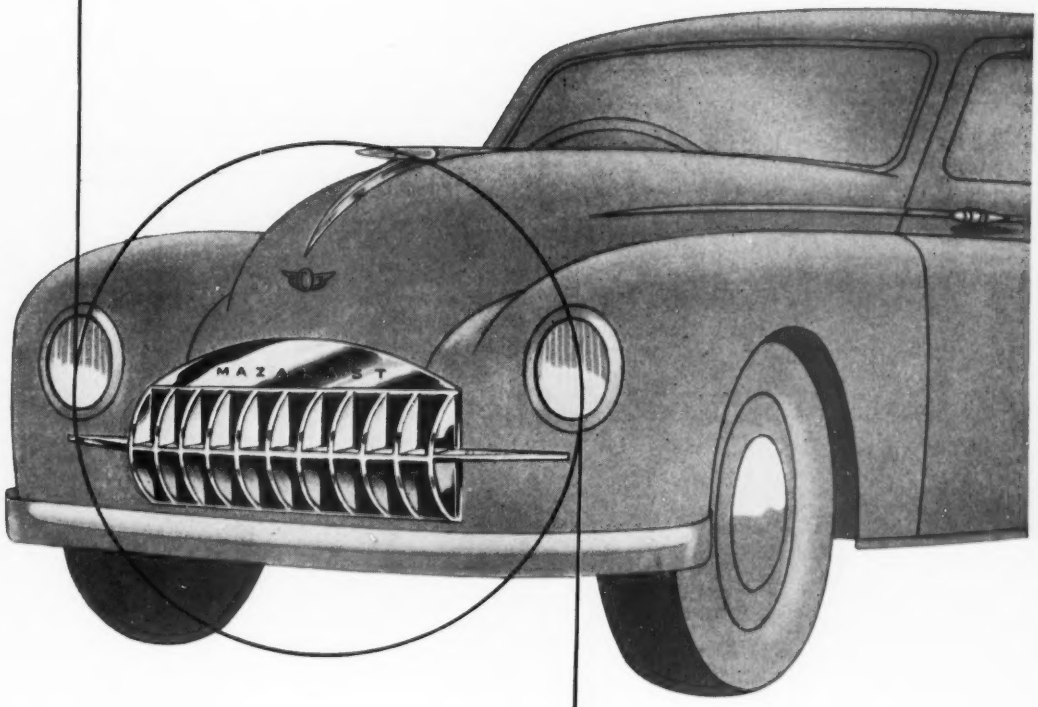

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